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THE BIOLOGICAL IRRADIATION FACILITY ("Janus" Reactor) DESIGN MANUAL

by

W. H. McCorkle, A. W. Pierce, and D. C. Thompson

ANL-6745
Reactor Technology
(TID-4500, 21st Ed.)
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60440

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June 1963

Operated by The University of Chicago
under
Contract W-31-109-eng-38
with the
U. S. Atomic Energy Commission

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I. INTRODUCTION

It is believed that a rather detailed description of the "Janus" Reactor Facility, well illustrated by the key drawings of the building and reactor features, and containing pertinent information about the nuclear and reactor radiation characteristics of the facility, will be useful to those who operate and utilize the Irradiation Facility.

This report is thus prepared with emphasis on those details which will supplement the Safety Analysis Report and the Reactor Operating Manual.

II. GENERAL DESIGN CONSIDERATIONS

The Division of Biological and Medical Research at Argonne National Laboratory has been engaged in an extended program of research on the biological and genetic effects of radiations arising from the fission process, particularly those radiations encountered by personnel engaged in the use of nuclear reactors. This research program, which is sponsored by the United States Atomic Energy Commission, is largely directed to evaluations of the effects of acute and chronic exposures to fission neutrons. In chronic exposures, the dosage rates are considered to be of magnitudes comparable with those experienced by personnel associated with day-by-day operation and use of nuclear research reactors and nuclear power plants for the generation of electrical energy and for propulsion or other purposes. The dosage rates for studies of acute radiation exposure of useful magnitudes are expected to be no more than from 10^4 to 10^5 higher than for the chronic exposures.

The dosage rates for chronic exposure studies are estimated to range from 0.1 rad/week to 50 rads/week, whereas, for the acute-exposure studies, they would probably run as high as 10^5 or 10^6 rads/week.

Studies of chronic exposure with large numbers of specimens and for the long times corresponding to the term chronic while concurrently studying acute exposure requires that there be two irradiation regions where chronic and acute exposure studies may be respectively performed without influencing each other. This requires two irradiation faces for the reactor and two irradiation cells isolated from each other. The neutron flux at one face should be from 10^4 to 10^5 higher than at the other face.

To obtain the maximum high-level dosage rate specified requires an incident thermal-neutron flux of about 10^{10} n/cm^2/sec or higher on the converter plate for the high-level irradiation cell.

To irradiate the large numbers of specimens required by the program within a reasonable length of time, makes it necessary to have large neutron converters and relatively large irradiation cells.

III. BASIC DESIGN PARAMETERS

The magnitude of the thermal-neutron flux (about 10^{10} n/cm^2/sec) which is required to be incident on the converter assembly of the high-intensity irradiation face in order to supply a dose rate of 10^6 rads/week to specimens in the acute irradiation cell was essentially the starting point in the design of the "Janus" Reactor (Biological Irradiation Facility). This value was experimentally determined from the Biological Irradiation Chamber installed at the thermal column of the CP-5 reactor. Here, there was a one-inch-thick converter plate of normal uranium metal which could be lowered into a 16 x 16-in. beam of neutrons emerging from the thermal column of the CP-5 reactor. Before the lowering of the converter plate, the thermal-neutron flux was approximately 2×10^{10} n/(cm^2)(sec). After lowering, the fission neutron dosage rate in the Biological Irradiation Chamber was of the order of 90 to 100 rads/min, equivalent to about 10^6 rads/7-day week.

The "Janus" converter is composed of uranium, highly enriched in U^{235}, alloyed with aluminum. The percentage of uranium in the alloy and the thickness of the alloy are such as to supply uniformly dispersed U^{235} atoms equivalent in number to those contained in a one-inch-thick plate of normal uranium of the same area. It is anitcipated that the fission-neutron-generating efficiency of a "Janus" converter should be somewhat higher than for a converter of normal uranium. From the above considerations, an incident thermal-neutron flux of approximately 2×10^{10} n/(cm^2)(sec) on the high-level converter was chosen as the basic design parameter.

Since it was desired to have a difference between the dosage rates of fission neutrons supplied by the neutron converters at the two irradiation faces of the order of 10^4 or greater, this required that the thermal-neutron fluxes incident on the two converters should differ by approximately that factor.

Ordinary water is the most suitable moderator to employ in and adjacent to the core of a small, relatively low-power reactor so as to provide the neutron-flux distribution and independence of irradiation face desired for the combined chronic and acute irradiations program. Experimental determinations[1, 2] in the Bulk Shielding Facility at ORNL and in the Battelle Memorial Reactor, which have compact, water-moderated cores of highly enriched U^{235} alloyed in aluminum, indicated that thermal-neutron fluxes of approximately 1×10^{12} n/(cm^2)(sec) for 100 kw of reactor power are obtained at the surfaces of these cores. The "Janus" reactor core is an arrangement of dimensions and composition similar to the two cited above.

In Appendix A of the "Janus" Safety Analysis Report,(3) calculations are given for the neutron-flux distributions throughout the radiation ports on a line passing horizontally through the centers of the high- and low-dose ports and the center of the core as planned for the "Janus" reactor. Selection of the reactor core location with respect to the two irradiation faces, the dimensions of the reactor core, the moderator-reflector-attenuator distribution, and the structural components has been guided by the requirements given above. The calculated thermal-neutron fluxes and distributions from the core surface to the irradiation faces of such a reactor arrangement, when operated at 100 kw of power, are given in Figs. 1, 2, and 3. These characteristics were obtained for a reactor arrangement which would be expected to furnish simultaneously similar neutron spectra at two irradiation faces of intensities which would differ by a factor of from 10^4 to 10^5. From the calculated curves of neutron-flux distribution for the "Janus" reactor, it may be estimated that a thermal-neutron flux of at least 1×10^{10} n/(cm^2)(sec) will be incident on the high-dose converter at a power level of 100 kw. However, to assure a flux of 2×10^{10} n/(cm^2)(sec) and to supply flexibility which it is anticipated may be desired by experimenters, a full-power operating level of 200 kw has been selected.

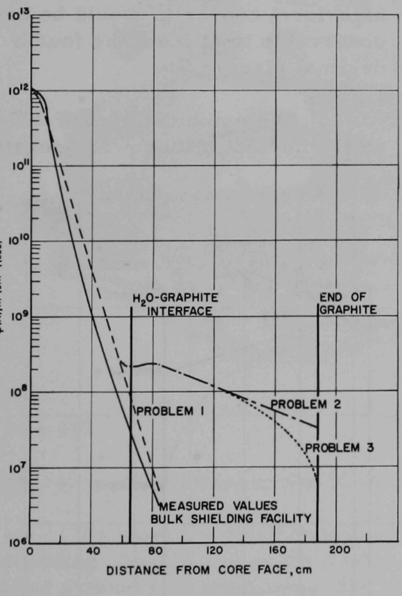

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Fig. 1. Plot of Neutron Flux from "Janus" Core to Low-level Converter

Independence of the performances of the two irradiation ports is another basic consideration. This is, however, a less rigid parameter which can be assigned limits which would not introduce excessive errors in the experimental measurements proposed for the planned irradiation programs or would not cause instabilities in the operating characteristics of the reactor. In general, it has been believed that variations of radiation intensities in one cell due to operating the other cell would not

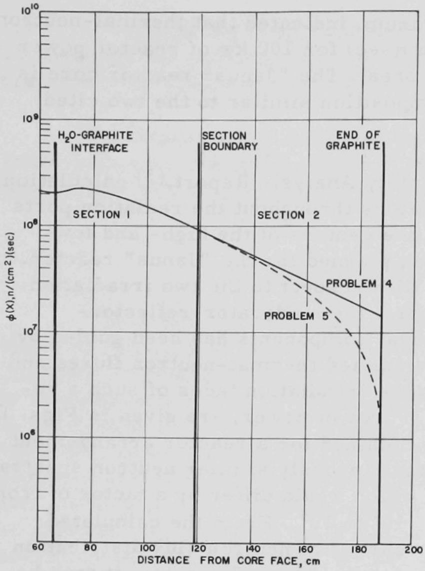

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Fig. 2. Neutron-flux Distribution in the "Janus" Low-level Zone

need to be kept below ±1% as far as the most refined experimental measurements are concerned. From the point of view of safety in operating control of the reactor, limits of $\pm\frac{1}{2}\%$ on control of the power level of the reactor should be acceptable. The requirement of supplying adequate space for installation of control rod drives, shutter and converter drives, plumbing, etc., would impose lower limits on dimensions of the reactor structure and shielding in excess of those needed for independence of the respective irradiation ports.

Calculations[3] show that the change in k_{eff} for the reactor due to insertion and removal of the high-level converter would be unobservable to at least the fourth decimal place.

The establishment of 200 kw as the normal, full-power operating

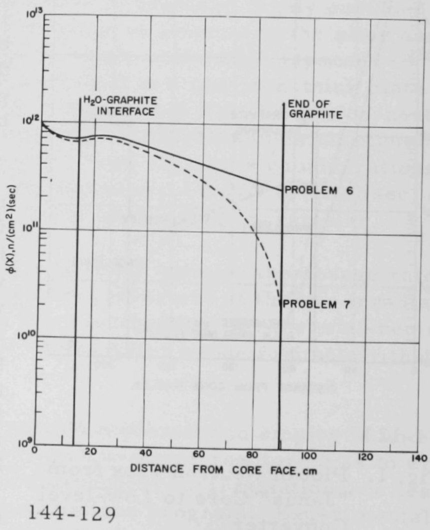

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Fig. 3

Plot of Neutron Flux from "Janus" Core to High-level Converter level requires selection of heat exchanger, cooling tower, and other heat transfer equipment which will assure dissipation of at least this amount of thermal power under normal summertime weather conditions. These components have been sized(4) to handle approximately 240 kw of heat dissipation under such weather conditions.

IV. DESCRIPTION OF THE FACILITY

A. General Features

The general arrangements of the "Janus" Irradiation Facility including the reactor, irradiation cells, specimen preparation rooms, reactor equipment room, ventilation, and air-conditioning installations are shown in Fig. 4.

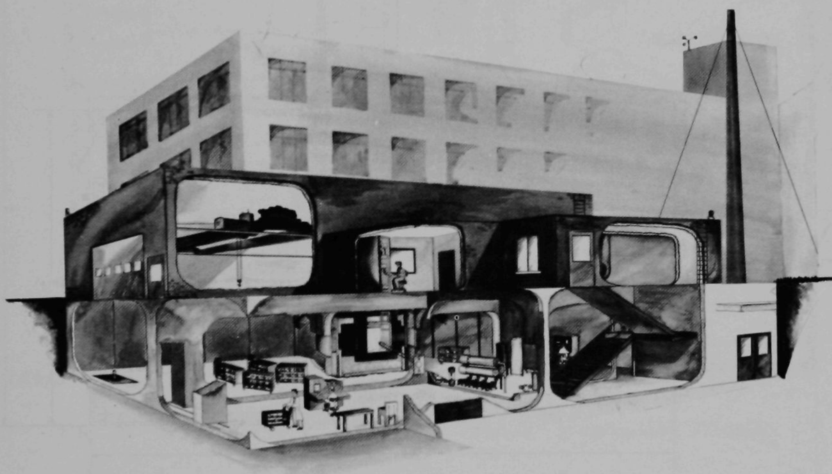

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Fig. 4. Artist's Conception (Cutaway) of the "Janus" Irradiation Facility

To meet the requirements of the general design considerations of providing chronic and acute fission-neutron irradiations simultaneously to large numbers of specimens, the surfaces of the neutron converters have been made generously large. The high-intensity face is approximately 17,000 cm^2, and the surface of the converter for the other face is approximately 27,000 cm^2. The acute irradiation cell has dimensions of approximately 8 ft x 16 ft with a 10-ft ceiling height. The chronic irradiation cell is approximately 23 ft x 23 ft with an 11-ft ceiling height. The general arrangement of the irradiation facility is further shown on the main floor plan, Fig. 5, and the service floor plan, Fig. 6.

The details of construction of the various reactor and building components are described in later portions of this manual by reduced reproductions of the assembly and detail working drawings or by reference lists citing drawings stored in the "Janus" drawing files.

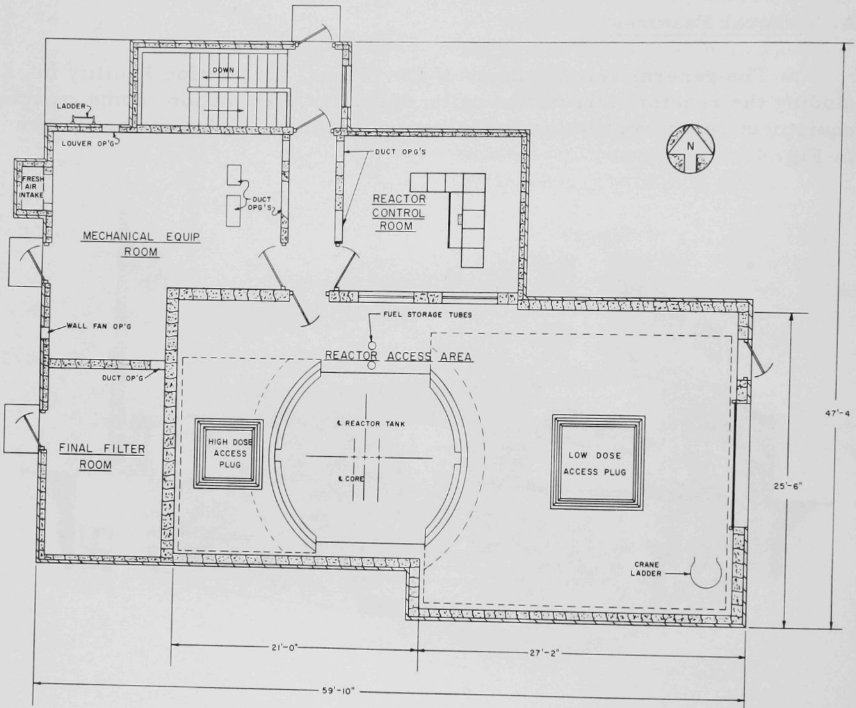

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Fig. 5. Main Floor Plan of the "Janus" Irradiation Facility

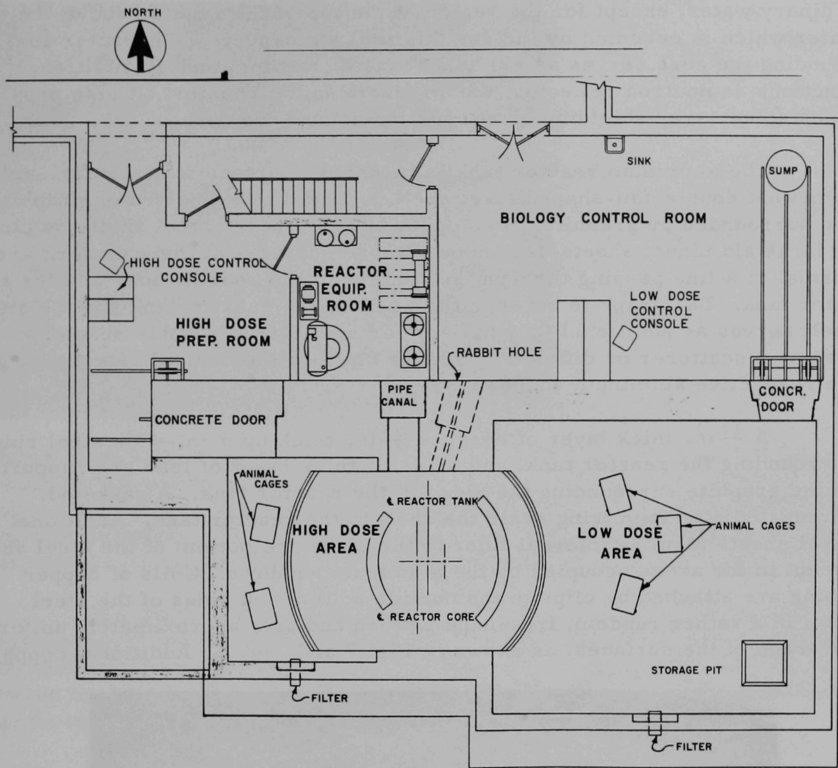

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Fig. 6. Service Floor Plan of the "Janus" Irradiation Facility

B. The Reactor

The "Janus" reactor has a vertical cylindrical core of uranium-aluminum alloy fuel assemblies highly enriched to approximately 93.5% in U^{235}. The portions of the core not occupied by the metal structural and fuel materials are filled with deionized ordinary water which serves as the moderator and coolant for the reactor. The core is mounted off center in a cylindrical, aluminum reactor tank with a thick and massive radiation-shielding cover. The axes of the core and reactor tank are parallel but are separated by a distance of $10\frac{1}{2}$ in.

The space outside of the core in the reactor tank which is not occupied by structural or other solid materials is filled by additional deionized ordinary water, except for the region at the top of the reactor above the water which is occupied by the gas (helium) atmosphere. The water surrounding the core serves as the heat transfer medium and, in addition, functions as neutron reflector, thermalizer, and attenuator. It also provides some γ-ray shielding or attenuation around the core.

The aluminum reactor tank is mounted in a sealed, irregular, and somewhat double-fan-shaped steel shell, where it is supported on graphite and surrounded by graphite. Two opposite faces of the steel shell are closed by large aluminum sheets or windows whose surfaces at their centers are normal to a line passing through the centers of the reactor core and the reactor tank. The graphite between the walls of the reactor tank and the steel shell serves as additional thermalizer for the neutrons in this space and also as a scatterer or diffuser to render uniform the neutron flux striking the respective aluminum windows.

A $\frac{1}{4}$-in.-thick layer of boral, a $\frac{3}{4}$-in.-thick by 5-in.-wide steel ring surrounding the reactor tank, and a 14-in.-thick layer of lead are supported on the graphite surrounding the sides of the reactor tank. A gasketed, corrugated aluminum ring seals the shell to the reactor tank. Additional boral sheets form an internal liner to the sides and bottom of the steel shell except in the areas occupied by the aluminum windows. Coils of copper tubing are attached by clips to the outside bottom and sides of the steel shell in a rather random, free-hand pattern and give approximately uniform coverage of the surfaces, as shown in Fig. 7 and Fig. 8. Additional copper

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Fig. 7. Bottom of Steel Shell with Cooling Coils Attached

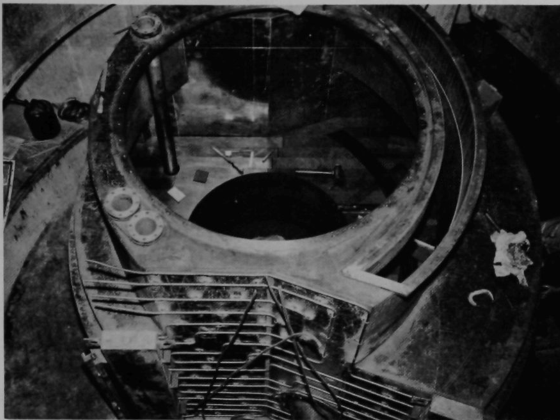

Fig. 8

Cooling Coils and Principal Graphite System Partly Installed

144-163

tubes, with their closed bottom ends arranged to terminate at various locations on the bottom and sides of the steel shell, have their top ends reaching above the sides of the steel shell. These tubes contain thermocouples or may accomodate thermocouples for the purpose of measuring temperatures at various points around the steel shell as may be found desirable.

The steel shell with the attached copper tubing is supported on a foundation of ordinary concrete. Legs or extensions with pads positioned the shell at the proper elevation above the rough foundation. The space between the bottom of the shell and the foundation was filled with concrete grout to provide uniform support over the bottom of the shell.

On the outside of the steel shell, in the regions adjacent to the aluminum windows, layers of lead were cast. The entire steel shell, flush with the frames where the windows are attached and level with the top of the shell, was surrounded with dense or with ordinary concrete as radiation-shielding requirements dictated. This concrete- and lead-encased structure and the reinforced building structure of which it became an integral part, form the thick wall or boundary zone which isolates the two irradiation cells from each other and from the adjacent specimen-preparation rooms.

Extending somewhat obliquely from one side of the steel shell on a horizontal axis, and directed from the neighborhood of the reactor core into the preparation room for the low-dose cell, is a stepped tube of generous dimensions. This stepped tube accommodates the pneumatic rabbit facility and its shielding. The rabbit facility is arranged to insert specimens of limited size into thermal-neutron fluxes up to approximately 10^{11} n/(cm^2)(sec) and quickly deliver them to a station in the low-dose preparation room. Provisions have been included for accommodating a delivery station in a future rabbit laboratory.

Outside of the reactor, various movable or removable shielding structures and mechanical devices are installed for controlling the release of reactor radiations into the radiation cells, for isolating radiation-wise the reactor from the surrounding regions, and for controlling the fission chain reaction associated with operation of the reactor.

The features of the reactor which have been mentioned above are shown by Figs. 9, 10, 11, and 12. Additional information and details regarding the items mentioned and the associated components may be obtained by consulting the subassembly drawings indicated on Fig. 10 and Fig. 12 along with their corresponding bills of materials.

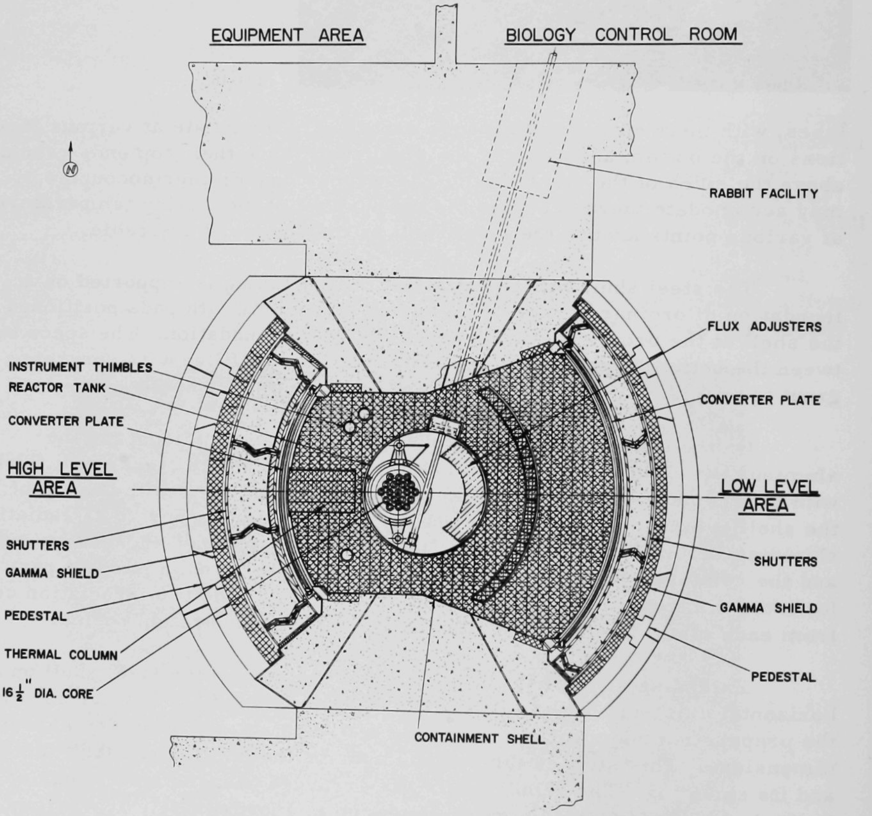

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Fig. 9. Horizontal Section through the "Janus" Reactor

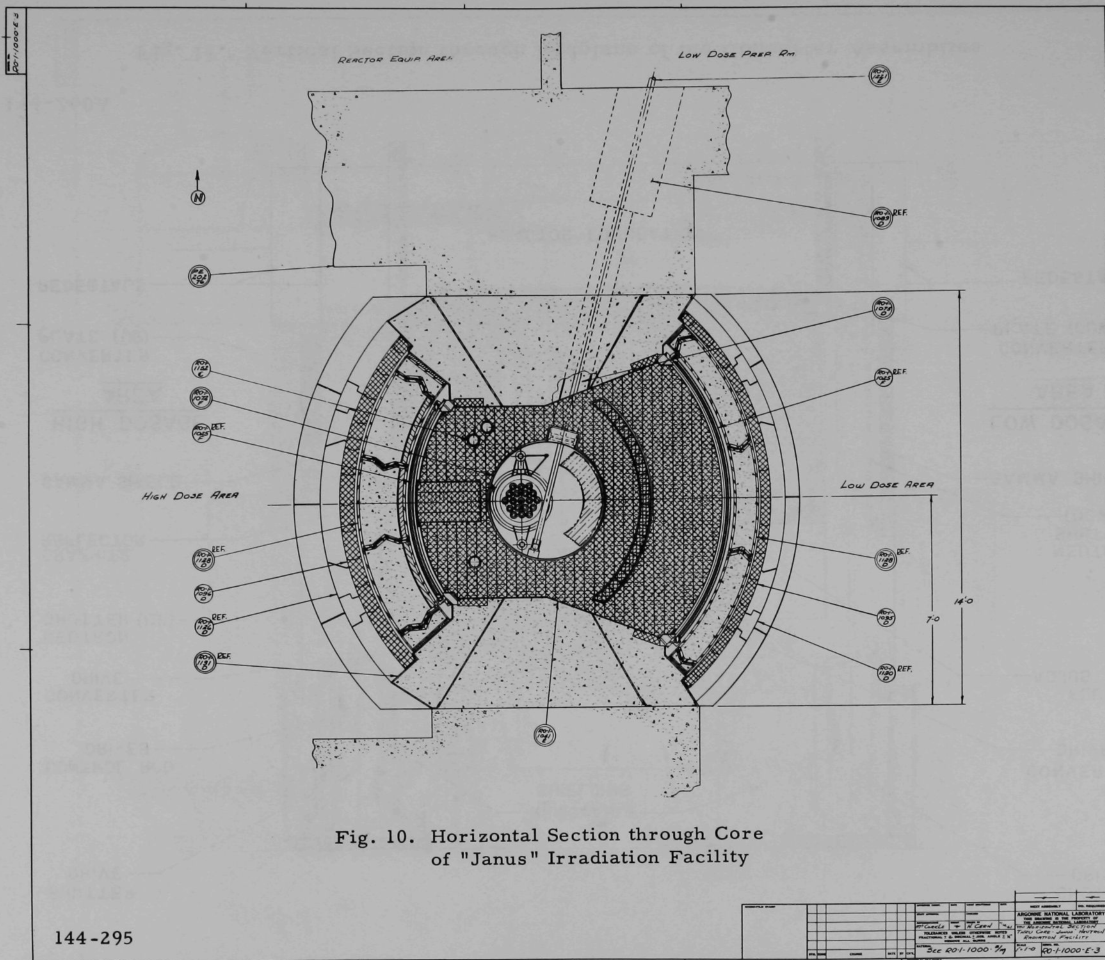

Fig. 10. Horizontal Section through Core of "Janus" Irradiation Facility

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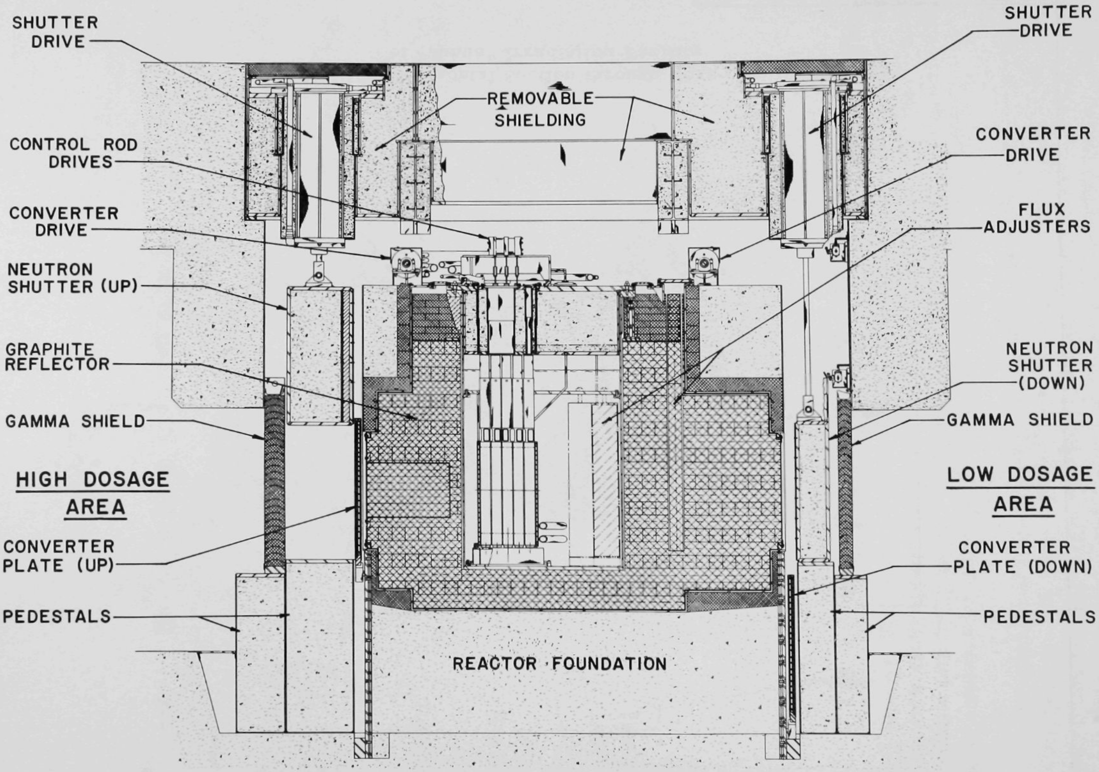

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Fig. 11. Vertical Section through Midplane of the Converter Assemblies

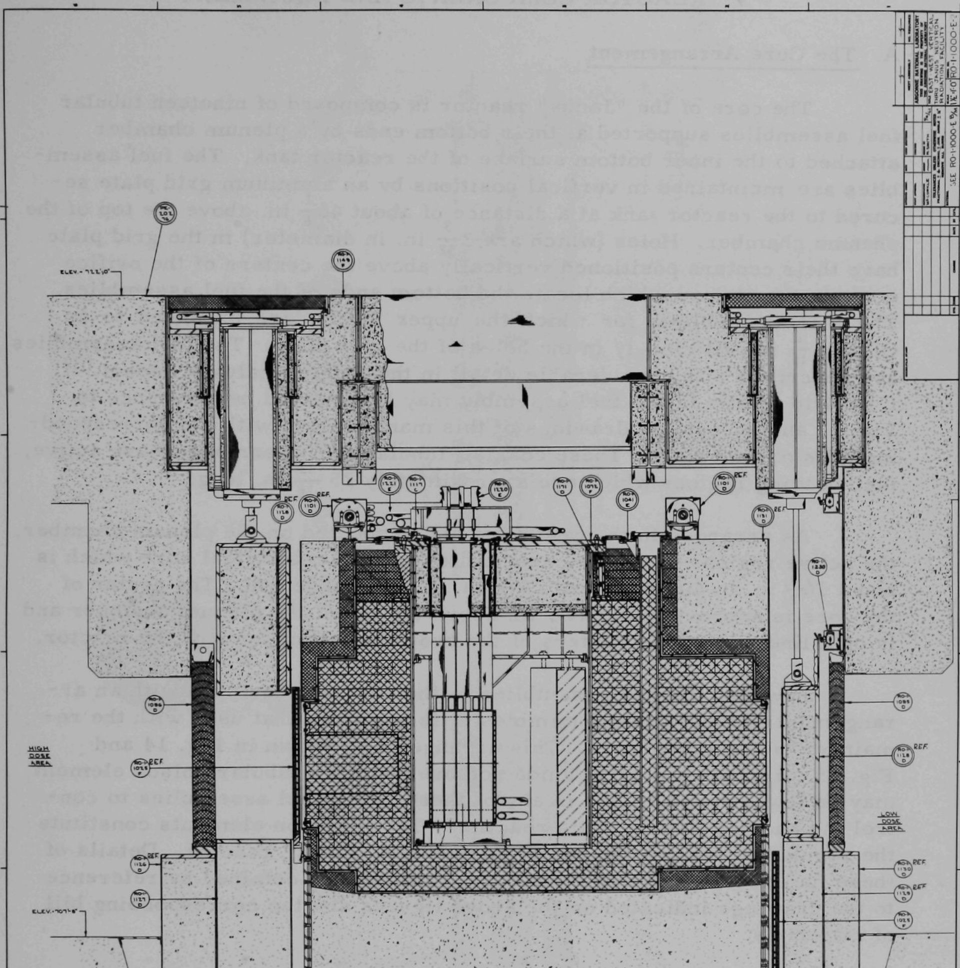

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Fig. 12. East-West Vertical through "Janus" Irradiation Facility

V. REACTOR COMPONENTS AND EQUIPMENT

A. The Core Arrangement

The core of the "Janus" reactor is composed of nineteen tubular fuel assemblies supported at their bottom ends by a plenum chamber attached to the inner bottom surface of the reactor tank. The fuel assemblies are maintained in vertical positions by an aluminum grid plate secured to the reactor tank at a distance of about $46\frac{1}{8}$ in. above the top of the phenum chamber. Holes (which are $3\frac{3}{32}$ in. in diameter) in the grid plate have their centers positioned vertically above the centers of the orifice seats in the plenum which locate the bottom ends of the fuel assemblies. The fuel assemblies, for which the upper $4\frac{1}{4}$ in. are expanded to an OD of $3\frac{1}{16}$ in., fit closely in the holes of the grid plate. The fuel assemblies are described with considerable detail in the Safety Analysis Report.(3) Complete details of the fuel assembly may be obtained by reference to Fig. 13 and associated drawings of this manual along with the corresponding bills of materials. These coaxial, tubular fuel assemblies have active, fuel-bearing regions which are approximately $25\frac{13}{16}$ in. long.

As arranged in the grid plate and supported on the plenum chamber, the active regions of the fuel assemblies form a cylindrical core which is about $16\frac{1}{2}$ in. in diameter and $25\frac{13}{16}$ in. in vertical length. The center of the core is approximately $17\frac{1}{2}$ in. above the top of the plenum chamber and is on a line joining the centers of the two irradiation ports of the reactor.

Seven of the fuel assemblies in the core are equipped with an arrangement of their central thimbles differing from that used with the remainder of the assemblies. This arrangement, shown in Fig. 14 and Fig. 15, provides a central guide rod over which a tubular poison element may be lowered and raised in any of these seven fuel assemblies to control the nuclear fission chain reaction. These poison elements constitute the regulating rod and the safety rods of the "Janus" reactor. Details of these fuel assemblies and the control rods may be obtained by reference to the drawings indicated on the above figures and the corresponding bill of materials.

The other twelve fuel assemblies in the reactor core may employ either central thimbles, which are fabricated of plain aluminum, or central thimbles, which contain approximately 40 g of uranium highly enriched in U^{235} and alloyed with aluminum. These uranium-bearing thimbles contain the fuel alloy jacketed in aluminum, and are positioned symmetrically above and below the center of the core to match the $25\frac{13}{16}$-in. length of the rest of the core. The fuel-bearing thimbles may be installed during the initial loading and calibration of the reactor to supply a clean cold k_{eff} ranging from about 1.5% $\Delta k/k$ to 7.5% $\Delta k/k$. This loaded-in reactivity will provide

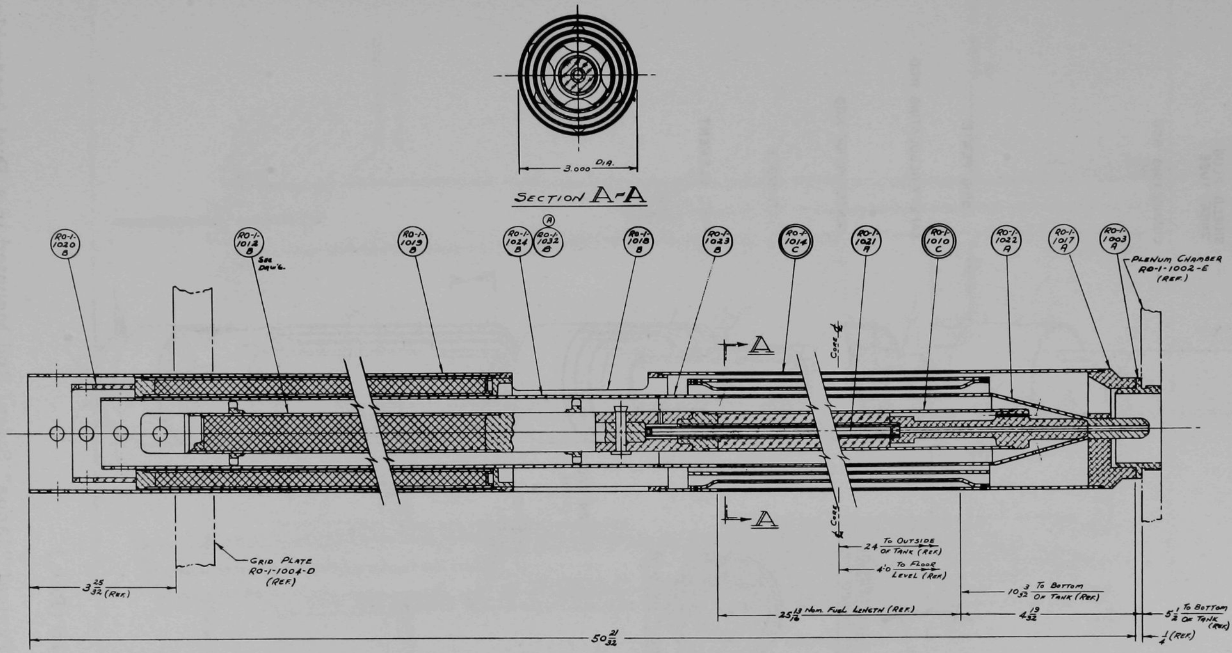

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Fig. 13. Fuel Assembly for the "Janus" Irradiation Facility

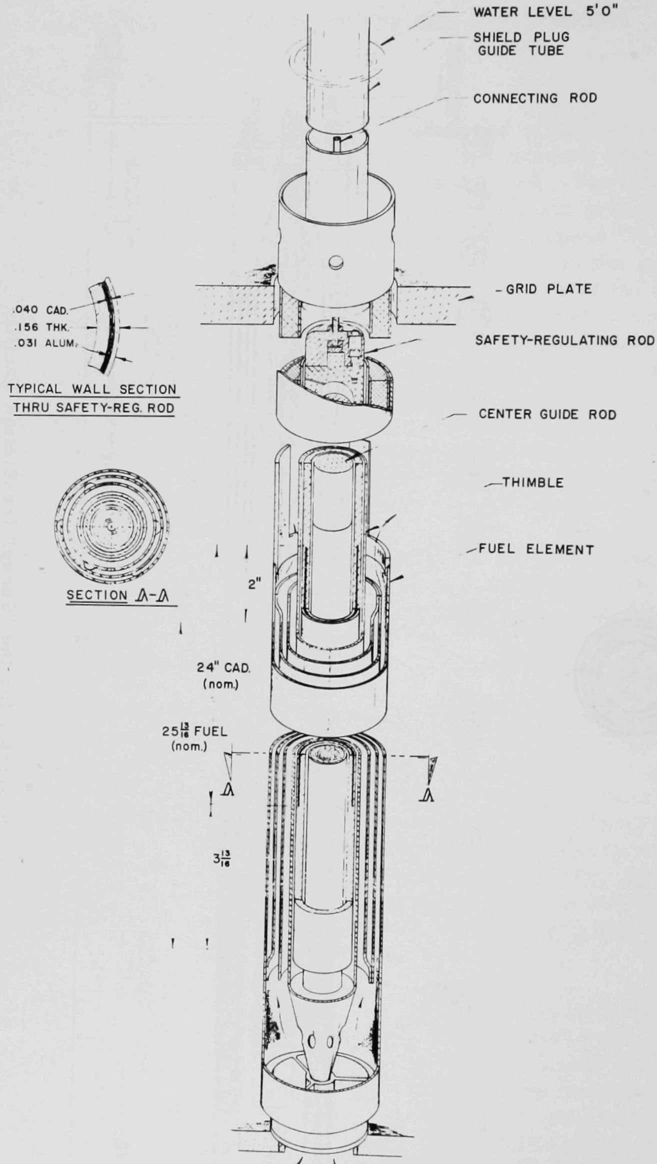

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Fig. 14. Typical "Janus" Safety Rod Mounted in a Fuel Assembly

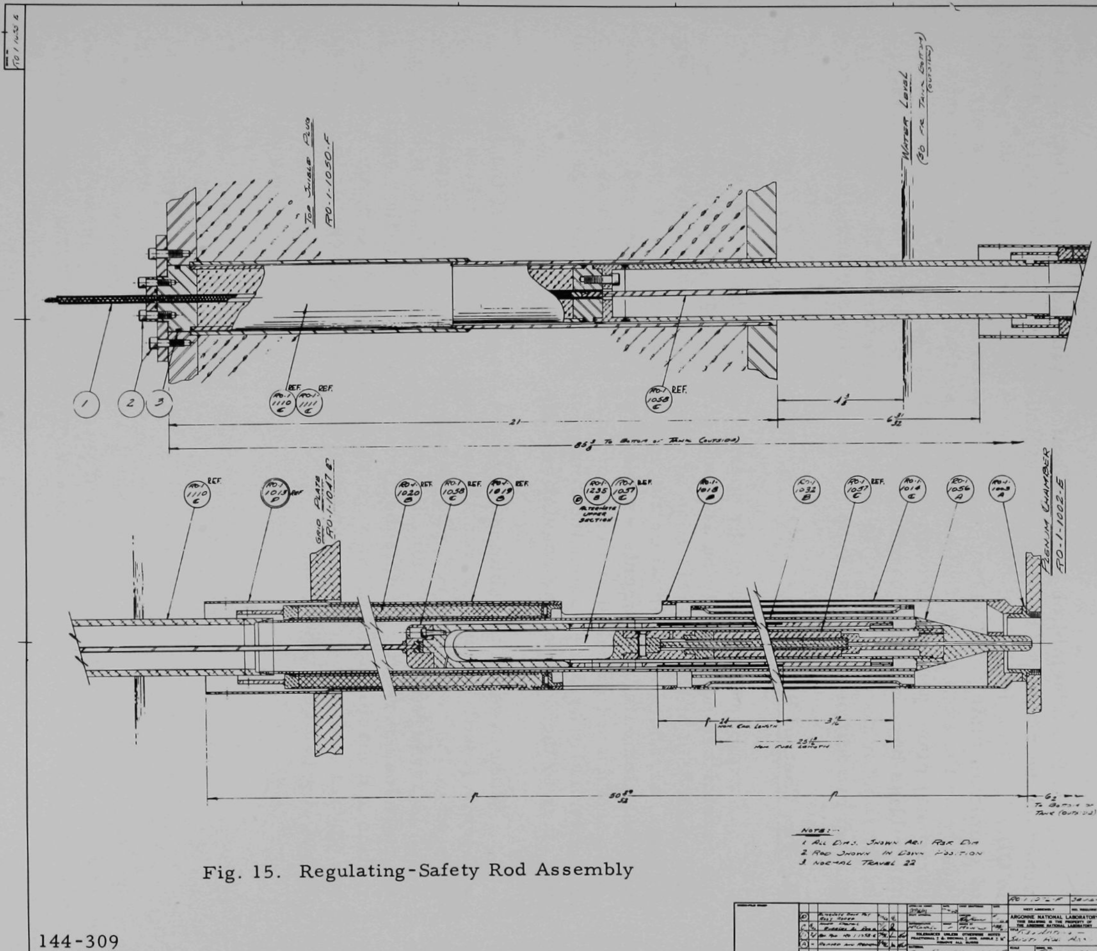

Fig. 15. Regulating-Safety Rod Assembly

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for xenon and other fission product poisoning, fuel burnup, and negative temperature coefficient loss of reactivity for a convenient span of operation at full power.

All fuel assemblies can have hollow cylinders of beryllium positioned on their axes. The beryllium cylinders are approximately 0.895 in. in OD., 0.380 in. in ID, and 24 in. long, with an inside and outside jacket of aluminum tubing of 0.049-in. wall thickness. These cylinders are located on the axes of the fuel assemblies so that their centers lie on a horizontal plane passing through the center of the core. When the fuel assemblies have become charged with fission products, the beryllium in the reactor core will serve to provide photoneutrons for reactor startup in addition to those supplied by an antimony-beryllium source.

B. The Control Rods

Startup, adjustment of the operating power level, and shutdown of the reactor are normally to be accomplished by manipulation of the control rods. Six of the controls rods are to serve as shim-safety rods. The seventh, arranged for manual or automatic adjustment of its position in precisely indicated increments, is known as the regulating rod. The shim-safety rods are located in two rows of three rods each. These rows are symmetrically arranged about the center of the core, one to the North and the other to the South of the regulating rod.

Withdrawal of the shim-safety rods from the core of the reactor will leave it with the built in reactivity of about 1.5% $\Delta k/k$ which is suppressed by the regulating rod. Outward adjustment of the regulating rod, which is arranged to move along the axis of the reactor core, will bring the fully loaded reactor from subcritical to critical. Further outward motion and manipulation of the regulating rod along the common axes of the central fuel assembly and the core will enable the reactor to be maintained at a selected power level.

The poison sections of both the shim-safety rods and the regulating rod are of similar construction. Figures 14 and 15 show the general features of the control rods as arranged in corresponding fuel assemblies. Details of the construction of the control rods may be observed in Fig. 16. The control rods are each constructed of 0.040-in.-thick cadmium sheet, rolled and fused into cylinders of approximately $1\frac{7}{16}$-in. OD. These cadmium cylinders, 24 in. long, are formed on heavy-walled aluminum tubes machined to accommodate the cadmium layers. They are then made into tubular sandwiches of cadmium between aluminum by drawing together, for each assembly, a larger aluminum tube slid over the cadmium-encircled, heavier-walled aluminum tube. The ends of each tubular sandwich are sealed by welding. At the bottom end of a tubular cadmium-aluminum assembly, a wear ring and guide of harder magnesium-aluminum alloy with a smaller ID is welded to the assembly. Similarly, a heavier-walled dashpot section of the harder alloy is welded to the top of the assembly. Small bleed holes communicate with the interior and exterior of the dashpot sections near their tops. A cap of hard alloy is arranged to be attached to the top of each tubular assembly by screws and to be secured to an extension rod for connecting a control rod to its drive mechanism.

C. The Reactor Tank

The plenum chamber, grid plate, fuel assemblies, control rods, and other items mentioned in connection with the core arrangement of the reactor are mounted in a $48\frac{3}{8}$-in.-OD aluminum tank. This tank has a wall thickness of approximately $\frac{1}{2}$ in. in the region around the core of the reactor. The bottom of the tank is approximately 1 in. thick. Near the top, the wall of the reactor tank is made heavier by welding to it a band of aluminum approximately $\frac{1}{2}$ in. thick and 10 in. wide. A rim, 2 in. thick and 5 in. wide, is welded to the thickened tank wall at the top. Stiffening gussets of $\frac{1}{2}$-in.-thick aluminum are welded to the underside of the rim and the outside of the thickened tank wall to form a reinforced flange at the top of the tank for supporting the reactor tank cover and radiation shield, as shown in Fig. 17.

Penetrations are provided in the tank cover and shield to accommodate aluminum pipes for circulation of the deionized reactor water through the fuel assemblies of the core and through an external heat-exchanger system. Other penetrations through the cover provide arrangements for circulating the helium atmosphere of the reactor, for installing a reactor water-level indicator, for a rotatable plug over the reactor core, and for accommodating other instrumentation openings which may be desirable during loading of the reactor.

A pneumatic rabbit and startup neutron-source assembly is welded into the reactor tank near the bottom of the tank. This U-shaped assembly, with one tube above the other, extends horizontally across the tank. It is

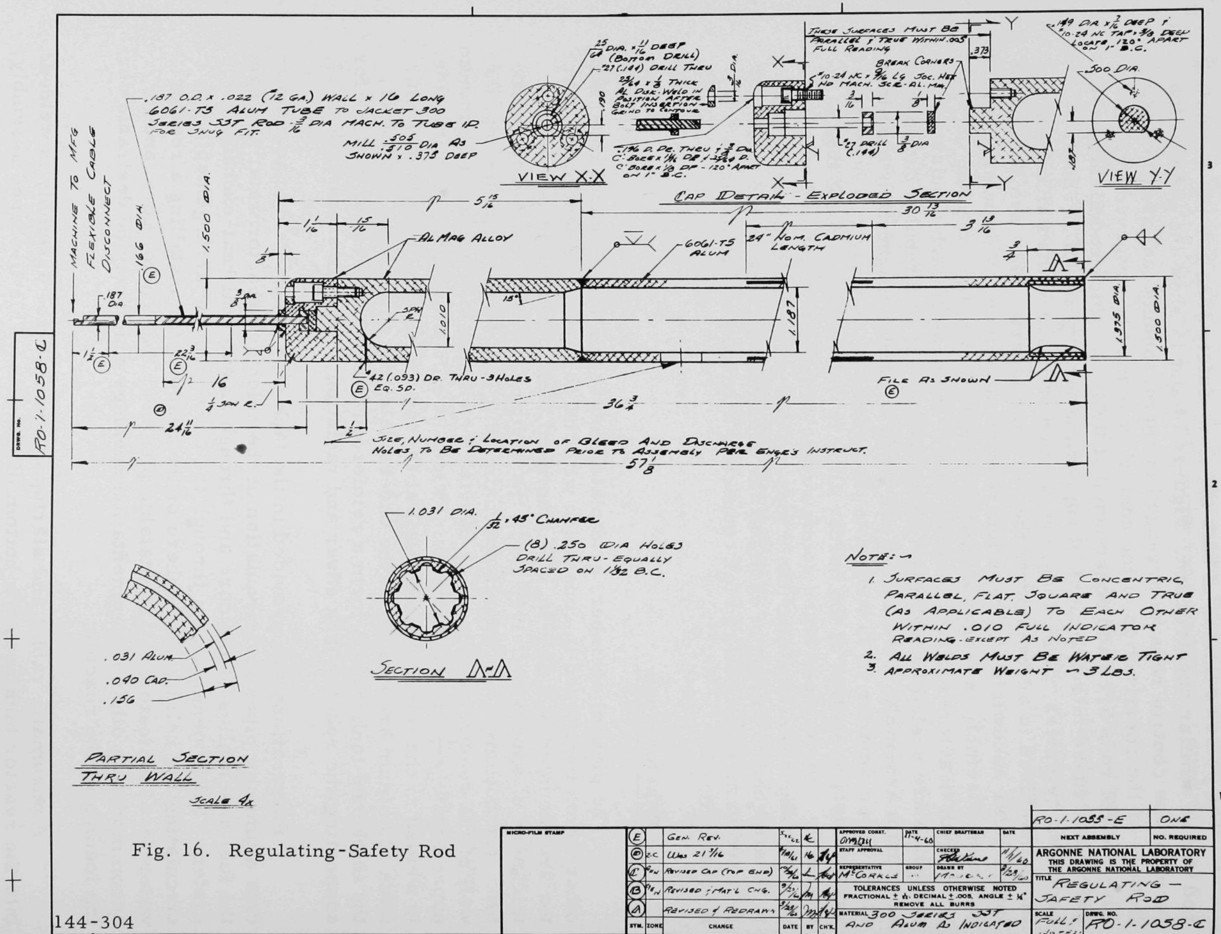

Fig. 16. Regulating-Safety Rod

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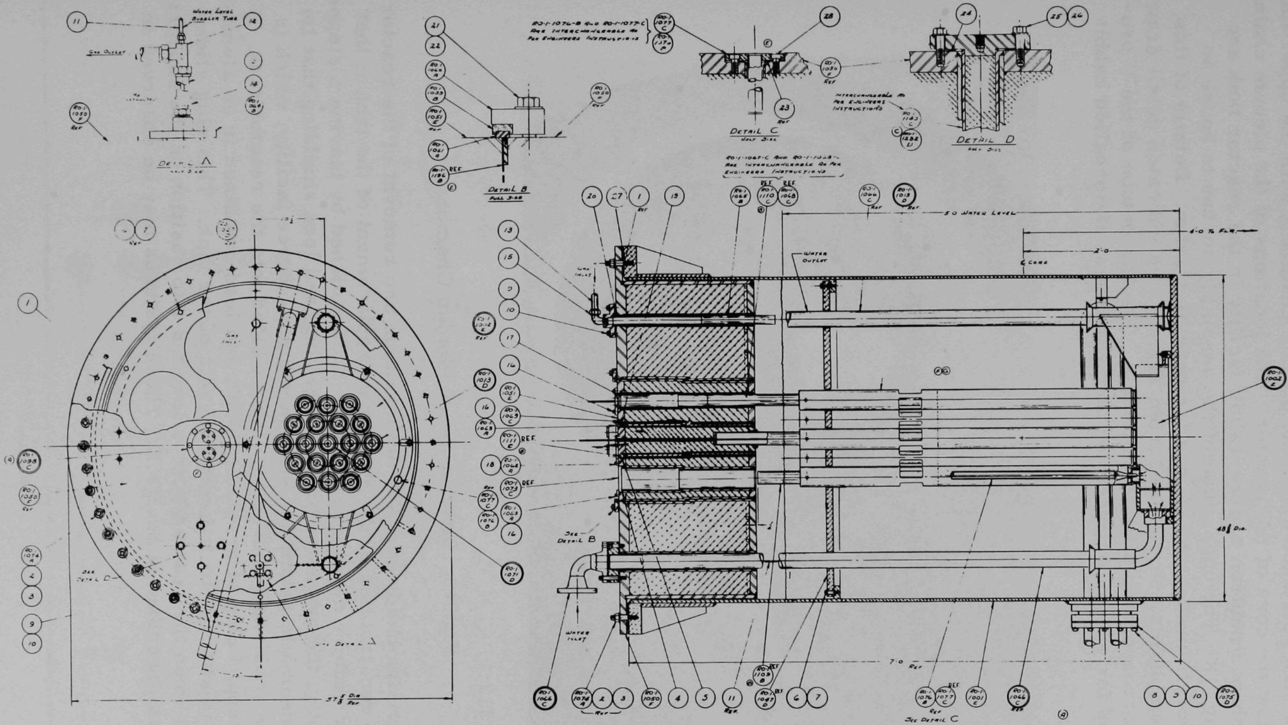

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Fig. 17. "Janus" Reactor Tank Assembly

positioned a short distance above the plenum chamber, with the upper tube slightly below the core of the reactor. The locations of the plenum chamber and the U-shaped neutron source-rabbit facility in the reactor tank are shown in Fig. 18. The upper tube of the assembly serves to house an antimony-beryllium neutron source for reactor startup. Details of this source assembly may be obtained from Fig. 19, the indicated detail drawings, and corresponding bills of materials. The lower tube of the U provides means for pneumatic insertion and withdrawal of so-called rabbit samples.

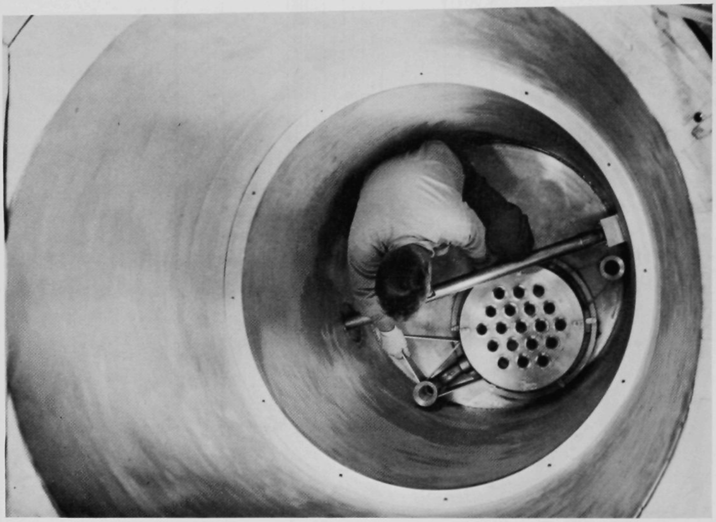

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Fig. 18. Installation of Plenum Chamber

Provision has been made for insertion and removal of the reactor tank during construction of the reactor or replacement of the tank if that should later become necessary. This is accomplished by leaving a stepped vertical slot in the graphite, Boral, steel ring, and lead shielding that lie above the pneumatic rabbit and startup neutron-source facility, which is bolted to the rabbit and source assembly welded into the reactor tank. A matching stepped plug of graphite, Boral, and lead contained in an aluminum frame is attached to stiffening gussets of the tank. This plug slides into the slot when the reactor tank is lowered into position on the supporting members described in Sec. V.E. These features may be observed in Fig. 20.

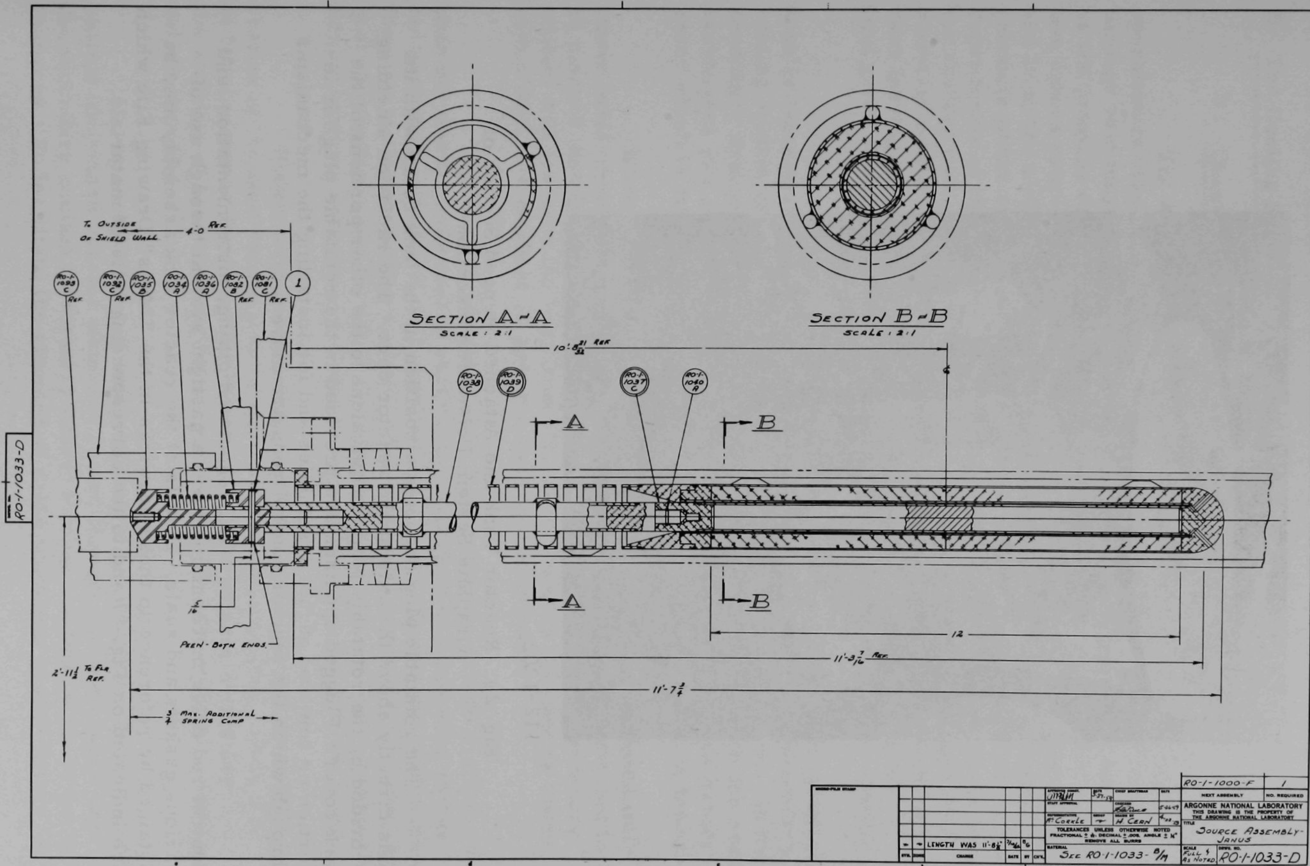

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Fig. 19. Source Assembly for "Janus"

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Fig. 20. Reactor Tank and Attached Stepped Section of Graphite System Poised for Insertion

The rotatable plug occupies a position in the tank cover with its axis directly above the axis of the reactor core. The radiation shielding provided by the rotatable plug is equivalent to the other portions of the tank cover. Plugged openings are provided in the rotatable plug for insertion or removal of fuel assemblies and for installing the mechanisms through which the reactor control rods are driven.

The entire reactor tank, associated piping, instrumentation, and control rod drive mechanisms form a gastight system through use of various gaskets and seals. Details of the reactor tank assembly may be obtained by reference to those drawings in the "Janus" Drawing File which are indicated on Fig. 17 and to the corresponding bills of materials.

D. The Cooling Systems

1. General Considerations

The heat generated in the "Janus" reactor during normal operation is very largely removed by circulation of the reactor water through twin main heat exchangers. This circulating system is known as the primary cooling system. The heat supplied to the primary system comes principally from the kinetic energy of the fission fragments, and from the alpha, beta, and soft gamma radiations from the fission products which are converted into heat in the fuel elements and the other constituents of the core. Some additional small amount of heat flows into the reactor water from the graphite, the Boral, and the dense shielding material outside of the reactor tank as a result of neutrons and gamma rays leaving the reactor tank. There is, of course, a small amount of heat given to the surroundings via the biological shielding of the reactor.

When the cooling systems are operating, the reactor-produced heat is transferred from the primary cooling system to the secondary cooling system through the twin heat exchangers mentioned above. In the secondary system, the heat is dissipated to the atmosphere from the heat exchangers to a cooling tower through the agency of ordinary laboratory water which is circulated through the heat exchangers and cooling tower.

When the "Janus" reactor is operated at the anticipated full-power level of approximately 200 kw, the primary coolant is expected to be pumped through the core at a rate of about 100 gpm. The secondary coolant will transfer the heat from the reactor tank to the cooling tower with a flow rate of about 70 gpm for each heat exchanger.

The two all-stainless steel heat exchangers (with room for a possible third), connected in parallel and equipped with isolating valves for each heat exchanger, have been selected as the means for heat removal from the primary cooling system. This was done to provide the full-power heat-dissipation capacity which is indicated above and to have sufficient flexibility for a wide range of operating powers below the 200-kw level.

Under normal operating conditions (200-250 kw), parallel operation of the heat exchangers is expected to be maintained. However, at reduced power levels either heat exchanger may be isolated to aid in the stability of heat removal by simply closing the proper 2-in. isolating valves (see Fig. 21).

In an effort to aid heat-exchanger maintenance, the primary coolant (deionized reactor water) is routed through the shell sides, and the secondary coolant (laboratory water) through the tube sides of the exchangers. To facilitate the cleaning of these tubes and to also insure the complete displacement of helium gas by the deionized water in the shell sides, the exchangers are mounted at an inclination of 45° to the horizontal.

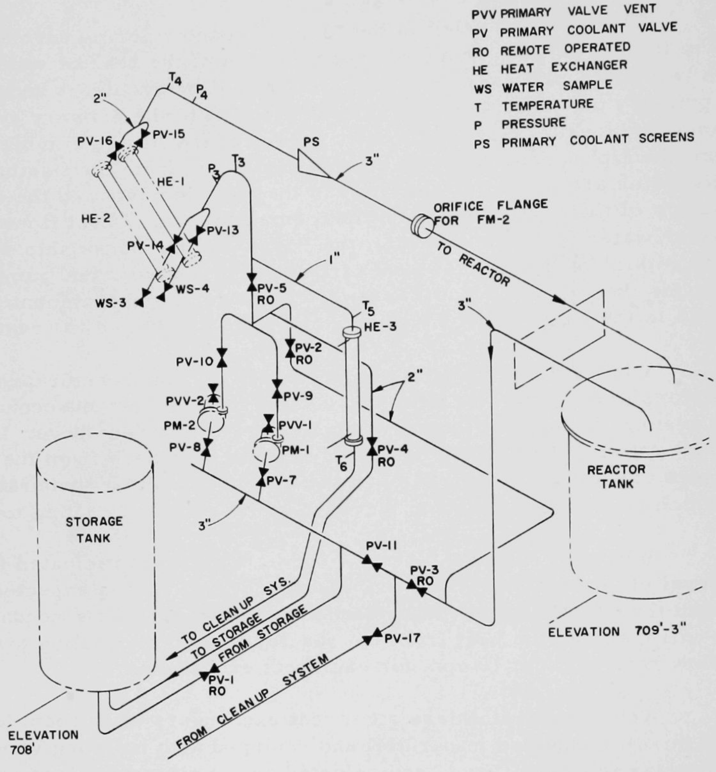

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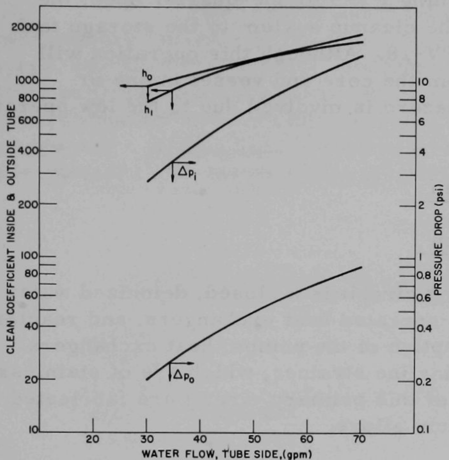
Fig. 21. Schematic Diagram of Primary Cooling System

It may be noted from Fig. 22 that, at normal circulation rates, the coolant pressures in the tubes will be somewhat higher than those in the shells of the heat exchangers. Because of this, the primary coolant could be subject to inleakage of the secondary coolant if failures should occur in the heat-exchanger tubes. The secondary coolant will possibly contain rather large amounts of dissolved polyphosphate and other compounds. Although sustained operation with inleakage could cause serious difficulties, early detection, by means of a change in reading of the conductivity cells in the primary coolant cleanup system, will permit a minimum amount of inleakage contamination. Upon detection of such inleakage, the reactor is to be immediately shut down and the coolant circulation completely stopped. After manual closure of valves PV-13, 14, 15, and 16, water samples from the individual exchanger shells may be taken via valves WS-3 and WS-4, preferably with the secondary coolant pumps operating. Analysis of individual samples will determine the leaking exchanger.



144-326

Fig. 22. Characteristics of Main Heat Exchanger

To reduce the time and amount of inleakage exposure of the reactor components further, the contaminated vessel water may be pumped to the storage tank through the cleanup system (see Fig. 23). To initiate this cleanup, assuming that the main heat exchangers are still in the isolated condition (valves PV-13, 14, 15, and 16 closed) and also assuming that the rest of the primary coolant system is in the normal operating condition, one need only

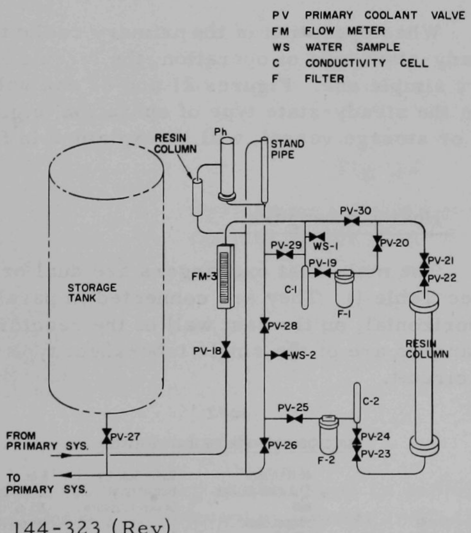


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Fig. 23. Reactor Coolant Cleanup System

close valves PV-5, 17, and 18 and open PV-27. Then, by starting one of the primary coolant pumps and opening PV-5 to one-quarter open, the desired flow (5 to 7 gpm) through the cleanup system to the storage tank may be obtained by adjustment of PV-18. Although this operation will remove all the primary coolant from the core and vessel in one or two hours (depending on flow), no hazard is involved due to the low operating power level of the reactor.

2. Primary Cooling System

a. General Description

The primary cooling circuit is a closed, deionized water loop with a pair of pumps, parallel-operated heat exchangers, and reactor and storage vessels. With the exception of the pumps, heat exchangers and their isolating valves, and the in-line strainer, which are of stainless steel construction, all components of this primary circuit are fabricated of aluminum or aluminum-magnesium alloys.

In anticipation that the primary coolant will be operated with a pH value of approximately 6.5 to 7.0, it was realized that the junctions of dissimilar metals were subject to possible galvanic corrosion. To prevent costly and time-consuming replacement of the corroded parts, sacrificial disks of aluminum were installed at all points where dissimilar metal junctions occur.

When operation of the primary coolant system is of the normal or steady-state type of operation, the circuit of the deionized water is a very simple one. Figures 21 and 23 are self-explanatory. Deviation from the steady-state type of operation, e.g., filling or draining of the reactor or storage vessel, will be explained in further detail in Appendix C.

b. Heat Exchangers

The main heat exchangers are dual or twin stainless steel exchangers (see Table I). They are connected in parallel and are mounted 45° from the horizontal, on the east wall of the reactor equipment room. The heat exchangers are of the single tube-sheet type with a four-pass cooling water circuit.

Table I

SPECIFICATIONS FOR THE HEAT EXCHANGER

Tube Surface	46 ft^2 (Each)	Baffle Spacing	6 in.
Heat Removal	73.2 x 10^4 BTU/hr	Weight (Dry)	130 lb (Each)
Tube Cleanliness	85%	Design Pressure	225 psi (Shell)
Primary Water Flow (Shell)	50 gpm (Each)		150 psi (Tubes)
Temperature at Primary Water Inlet	125.6°F	Test Pressure	338 psi (Shell)
Temperature at Primary Water Outlet	111.0°F		225 psi (Tubes)
Secondary Water Flow (Tubes)	70 gpm (Each)	Number of Tubes	116 (Each)
Temperature at Secondary Water Inlet	89°F	Size of Tubes	3/8 x 22 BWG
Temperature at Secondary Water Outlet	100°F	Material	Type 316 Stainless Steel (All)

c. Primary Coolant Pumps

The reactor water may be circulated by one or both of two primary coolant-circulating pumps (see Table II). These are single-stage, standard end-suction, centrifugal pumps, horizontally mounted on steel pedestals directly below the main heat exchangers. Their pumping characteristics are indicated in Fig. 24. These monobloc motor-mounted pumps are ruggedly constructed to give long and dependable service. They are equipped with conventional splash-proof induction motors as the drivers.

Table II

SPECIFICATIONS FOR PRIMARY COOLANT PUMPS

Capacity	100 gpm	See Fig. 24
Total Head	30 ft	
N.P.S.H.	8 ft	
Impeller Diameter	6-3/4 in.	
Motor Horsepower	1-1/2 hp	
Speed	1750 rpm	
Voltages (3-phase, 60-cycle)	220/440 v	
Pump Material	300 series stainless steel	
Seal	Mechanical type E.A.	

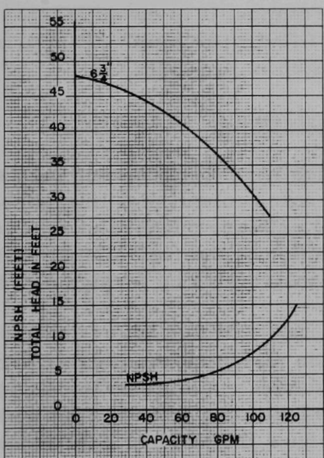

Fig. 24

Performance Curves of Primary Coolant Pumps

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Because the primary coolant must be considered as a hazardous fluid, which makes the necessary leakage from standard stuffing boxes objectionable, both pumps have been equipped with mechanical-type shaft seals (see Fig. 25). No attention or adjustments to these seals are required; except for a possible slight initial leakage, they should operate with no leakage.

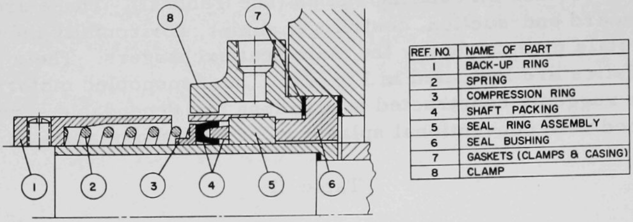

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Fig. 25. Mechanical Shaft Seal of Primary Coolant Pumps

Under normal operating conditions, single pump operation is expected to be maintained with the other pump available as a standby. Simultaneous operation of both pumps is permissible providing that, prior to starting the second pump, a check is made to insure that its discharge valve is initially closed, and the pump motor shaft is observed not to be operating in reverse rotation.

Before starting any of the pumps, it is essential that both the casing and suction pipe be completely filled with liquid. This priming may be accomplished by the method indicated in Appendix C.

d. Primary Coolant Screen Assembly

The primary coolant screen is of the minimum-resistance design and is located in the horizontal reactor coolant inlet line, directly above the twin main heat exchangers. The primary purpose of this screen assembly is to afford the necessary protection to the fuel-element cladding and coolant channels from laceration and obstruction by foreign objects carried along with circulating coolant.

Because of the construction material (stainless steel) and also because the coolant-flow-measuring device contains no moving parts that could possibly fail and be carried away with the effluent, the location of the screen assembly was selected to reduce the number of pipe junctions subjected to galvanic action.

Complete details of the screen assembly may be found in the assembly drawing RO-1-1182-C.

e. Primary Coolant Storage

The primary coolant storage tank, which has a capacity of ~750 gal, is of all-aluminum construction and is located in the vertical position at the southwest corner of the reactor equipment room.

Because of rather generous dimensions of this tank, 4 ft in diameter and standing slightly higher than 10 ft, insertion of this vessel into the reactor equipment room was made prior to completion of the building construction.

The $\frac{1}{2}$-in.-thick aluminum flanges that are bolted and gasketed to both the top and bottom of this tank contain the welded aluminum pipe fittings that provide entrance and exit passage for both the primary coolant and its helium atmosphere.

This vessel is intended for storage of all or any part of the primary coolant. No attempt was made to use this vessel as a safety device, such as a dump tank. The somewhat similar radial dimensions and difference of relative elevations of the reactor and storage vessels (see Fig. 21) do provide a means of lowering the primary coolant in the reactor vessel to any desired level that is easily predetermined by simple addition or removal of the excess primary coolant maintained in the storage tank. However, due to the relatively long time required for this operation, it must be considered as an anti-startup device rather than a shut-down feature.

3. Secondary Cooling System

a. General Considerations

The secondary circulating water system serves to remove that quantity of heat which is transferred to the primary coolant loop from the reactor fuel elements, and thus forms a balance of heat input and removal to the primary coolant. The means of transferring the heat from the primary coolant to the secondary water is accomplished by convection and conduction in the twin heat exchangers. Heat removed by the secondary circulating water is to be dissipated to the atmosphere by means of a standard, package-type cooling tower.

The secondary cooling system has a capacity of only 225 gal and will circulate 140-160 gpm. Of this total, 140 gpm will be directed through the twin heat exchangers, thus leaving 10-20 gpm of cooling water for the anticipated shield or auxiliary cooling system.

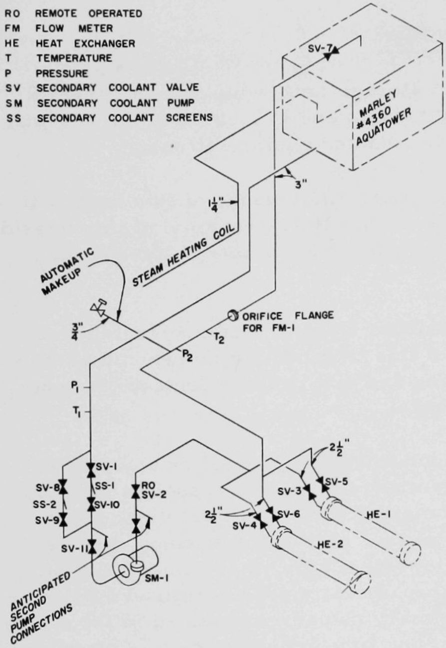

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Fig. 26. Schematic Diagram of Secondary Cooling System

Because of the simplicity of the secondary cooling circuit, the isometric piping diagram found in Fig. 26 is self-explanatory. If further details are required, they may be found on plant engineering drawing PE-202-83.

b. Cooling Tower

The heat removed by the secondary circulating water is dissipated to the atmosphere by a Marley Model 4360 Aqua Tower (see Table III), located north of the reactor building. The design requirements of this tower are to cool 140 gpm of water from 100°F to 88°F at a wet bulb temperature of 78°F. The cooling tower casing, basin, fan, and fan venturi are fabricated of heavy gage steel, then hot-dip galvanized for corrosion protection.

The estimated volume of water held in the all-metal basin is close to 100 gal. The make-up rate to the cooling tower is estimated to be 17 to 20 gpm.

Table III

COOLING TOWER SPECIFICATIONS

Quantity of Water	140 gpm	Speed of Motor, rpm	1800/900
Temperature of Water to Tower	100°F	Fan-motor Rating	3 hp, 3/60/440
Temperature of Water from Tower	88°F	Number of Fan Blades	9
Wet Bulb Temperature	78°F	Material of Fan Blade	Steel
Spray Loss (percent)	0.2	Material of Fan Shaft	Stainless Steel
Estimated Evaporation Loss (percent)	1.0	Bearing Material for Fan Shaft	Bronze
Number of Cells	1	Fill Material	Redwood
Number of Motors and Fans	1	Material for Drift Eliminators	Redwood
Type of Drier (fan)	Belt	Pump Head	8.5 ft
Diameter of Fan	40 in.	Dry Weight	2,835 lb
Speed of Fan, rpm	720/360	Maximum Operating Weight	5,655 lb

Although laboratory water is used for the secondary cooling system, it will be more or less continually treated with sulfuric acid and polyphosphate compounds to maintain a pH and residual phosphate value that will be conducive to a minimum tendency for scale formation by the water.

Again, to maintain versatility in the heat-removal equipment, a sheet metal damper extension containing an opposed blade damper was installed on the dry air side of this cross-draft tower. The blade damper is operated by air, through a Johnson Service Company #4 Damper Motor, that is in turn controlled by a T-800 thermostat and thermo bulb mounted in the tower basin close to the opening in the suction line. To protect the tower basin from freezeup and to aid reactor startup in cold weather, a $1\frac{1}{4}$-in. steam line has been installed in the tower basin. The automatic feature of the steam line, tower blade damper, and water make-up will require little or no attention by the operating personnel.

c. Secondary Coolant Pumps

The two secondary coolant pumps located below the twin heat exchangers at the northeast corner of the reactor equipment room are of the type #2-RVN-5, single-stage, end-suction, vertically split, Cameron centrifugal motor pumps (see Table IV). Each pump is fitted with iron casing, bronze impeller, bronze shaft sleeve, and is close coupled through a heat-treated steel shaft to a 5-hp, ball-bearing, splash-proof, squirrel cage induction motor. The performance characteristics of the pumps are given in Fig. 27.

Table IV

SPECIFICATIONS FOR SECONDARY COOLANT PUMPS

Liquid	Water
Specific Gravity	1.0
Suction Head	Flooded
Flow, gpm	250
Total Head, ft	50
rpm	3450
Efficiency	67%
B.H.P.	4.7
Motor	5 hp/3/60/220/440
Impeller Diameter, in.	5

Operation of the secondary coolant pump is very similar to that of the primary pumps. It was mentioned in Sec. D.2.c. that, under normal operating conditions, single pump operation is expected to be maintained, the other pump being available as a standby. However, simultaneous operation of both pumps is permissible providing that, prior to starting the second pump, a check is made to insure that its discharge valve is closed, and the pump motor shaft is observed not to be operating in reverse rotation. The preceding limits on simultaneous pump operation apply to the secondary coolant pumps as well.

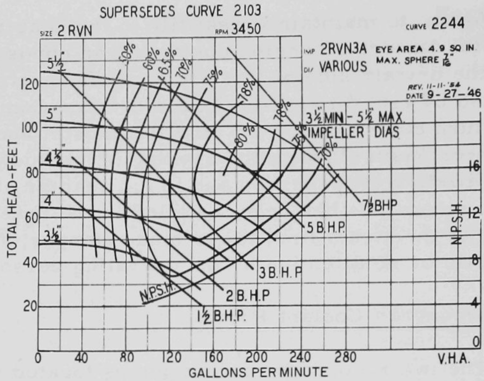

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Fig. 27. Performance Characteristics of Secondary Coolant Pumps

d. Secondary Coolant Strainers

Two Y-pattern sediment separators are installed in the 3-in. suction line, slightly above the secondary coolant pumps on the north wall of the reactor equipment room. Simple design, rugged construction, and large screening area make these separators exceptionally efficient in protecting equipment against damage from dirt, grit, scale, and all foreign matter in the water lines. The separators not only prevent passage of foreign matter, but also furnish a pocket for its accumulation, from which the matter can be easily removed through the blow-off connection. The two Y-pattern separators, mounted in parallel, are equipped with the necessary isolating valves to facilitate changeover and cleaning without system shutdown.

4. Auxiliary Systems

a. Primary Coolant Purification

(1) General

The primary purpose of a purification or so-called cleanup system is to protect the fuel-element cladding for its full core life or cycle time from corrosion and scale formation that could, if left undetected, lead possibly to failure of the cladding material and dispersion of fission product into the coolant.

It is a well-established fact that water purity is a major factor in the corrosion resistance of reactor systems. Soluble ions and insoluble corrosion products that would accelerate corrosion, erosion, or deposition on heat-transfer surfaces must be continually controlled. In the "Janus" reactor, this control is accomplished by removal of the soluble ions and insoluble particles through retention in the mixed-bed ion-exchange resins and their protective filters.

Under normal operating conditions, 4-5 gpm of the primary coolant is side streamed from the pressure side of the primary circulating pumps (see Fig. 21) through a 1-in. stainless steel-pipe heat exchanger, and then on through to the purification equipment that is located on the west wall of the reactor equipment room. After the side stream is passed through the purification equipment, it will normally be returned to the main coolant stream via the suction side of the circulating pumps. Installation of the purification system is shown in Fig. 23. It consists of a flow meter, conductivity cells, filters, resin column, pH flow cell, and the necessary local read-out instruments, water-sample stations, valves and pipings.

(2) Flow Meter

The flow meter, installed in the reactor purification system, is a Brooks Model #1140, size 10, full-view rotameter that is calibrated for 0-10 gpm (at a specific gravity of 1.0). This pipe-line-mounted instrument is well constructed to withstand the stresses and vibrations inherent in piping installations. The heavy-wall glass tube with its Teflon packing is well protected by a safety shield composed of stainless steel and safety glass. All metal parts that come in contact with the coolant are 300 series stainless steel. Table V relates the maximum operating temperatures and pressures.

Table V

SPECIFICATIONS FOR FLOW METER

Max Pressure (psig) at 200°F	Max Temp (°F)	Pressure Reduction above 200°F (psi/°F)
200	400	0.45

It may be seen from Table V and the operational curves of the primary coolant pumps (see Fig. 24) that, if for some reason maximum pump pressure at maximum operating temperature of the reactor coolant is applied to the flow meter, a safety factor of ten (10) or greater remains.

(3) Conductivity Cells

The conductivity cells used to monitor the quality of the primary coolant both before and after its passage through the mixed resin bed are of the insertion type. This insertion-type cell will permit removal, repair, or replacement without shutdown of the purification system. The Industrial Instrument, Inc., cell model #CEL-I-(SS)-002-K-A used is so constructed that all the wetted metal parts, including the isolation valve, are of Type 316 stainless steel. Temperature elements are included in each cell for automatic temperature compensation. Detail dimensions of this insertion-type cell and its electrical schematic may be found in drawing No. RO-1-1294-C.

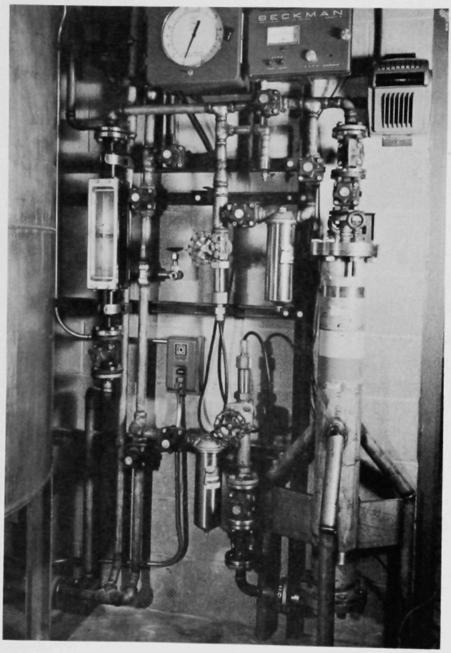

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Fig. 28. "Janus" Cleanup System and Associated Instruments

Readout of either cell in specific conductance (micromhos/cm^3) is accomplished through an Industrial Instrument Type R1 indicator controller. This indicator is mounted on the west wall of the reactor equipment room directly above the purification system (see Fig. 28). Although this indicator controller is the only means available for conductivity readout, it may be easily equipped with the necessary relays to sound an alarm at the reactor control center when coolant quality reaches a predetermined limit.

(4) Filters

The filters selected for installation before and after the mixed resin bed are Ful-Flo Models SSB 10 3/4. The shell and internal filter-cartridge holder are fabricated of Type 316 stainless steel. Each unit contains one cotton-thread, honeycomb filter tube. Although a 20-μ-rated filter tube was selected for the initial operation of the system, a 5- to 10-μ-rated filter tube may be used as water quality improves.

The pre-filter unit is expected to remove and trap about 90 percent of the insoluble contaminants and prevent plugging of the mixed resin ion columns.

The after-filter is intended to remove and retain any resin particles that may be flushed out of the resin bed.

During normal operation, the radioactivity levels of the filters are expected to be low, and no permanent shielding is furnished. However, the filter units are installed close enough to the resin column so that a portable shield section may be used to reduce activity levels produced by all three items.

(5) Mixed Resin Bed

The mixed resin ion exchange column is the major component of the purification system. The container used for the resin is constructed from Type 304 stainless steel. It has a 5-in. ID and is 44 in. long (see Drawing RO-1-1286-D). This unit contains close to 0.5 ft^3 of a uniform mixture of ILLCO NR-1 (8% DVB cation exchanger in the hydrogen form) and ILLCO NR-2 (Type I anion exchanger in the hydroxide form) in the approximate proportion of 1:1. Due to the present practice of not regenerating radioactive resins, no provision for back washing was incorporated in the design of the resin container.

The selection of a nuclear grade of resin was mandatory due to the fact that ordinary ion-exchange resins contain soluble organic matter, heavy metals, and chlorides that could contaminate the reactor coolant system. In the so-called reactor-grade resins, organic materials are removed by washing with hot water and alcohol. The inorganic impurities are removed, at least to a minimum level, by cycling with strong acids and caustic soda. The resins are then regenerated, using regenerant chemicals of suitable purity.

The mixed-bed resin column is expected to maintain reactor coolant quality close to a 1-megohm specific resistance and a pH of 6.5 to 7.0.

(6) pH Flow Cell

A Beckman #18501 stainless steel flow chamber, equipped with the proper glass electrode, reference electrode, thermo compensator, and pH read-out indicator, was installed as part of the purification system, and is located adjacent to the storage tank on the west wall of the reactor equipment room.

The valves and piping that provide the connection of the flow chamber to the purification system have been arranged to allow pH measurement of reactor coolant before or after its flow through the mixed resin bed.

The normal precautions to prevent overpressurizing of the flow chamber and contamination of reactor coolant by electrolyte entrance due to breakage of the glass reference electrode have been taken. To prevent overpressurization of the flow chamber, a simple standpipe has been installed to limit the hydrostatic head that may be applied (see Fig. 23).

A relatively small, mixed-bed resin column is installed on the discharge side of the flow chamber to insure a minimum of contamination to the reactor coolant from a possible introduction of a potassium chloride (KCl) solution in case of accidental breakage of the glass reference junction. Details of the pH cell resin bed may be found in Drawing RO-1-1285-C.

b. Skimmer and Level-control System

(1) General

Experience with similarly constructed reactors has shown that a surface film or scum, consisting of aluminum and aluminum oxide particles, forms on the surface of the coolant-reflector inside the reactor vessel. Although this surface film seems apparently harmless to most reactor systems, with the exception of a possible slight increase in the rate of water decomposition, tests with the "Janus" safety rods and operational experience with the CP-5 regulating rod indicate that this surface film may well be the major factor determining operational or cycle life expectancy of any control device that has its hardware penetrating it.

To maintain a control- and safety-rod cycle life expectancy that may be in keeping with the philosophy of the reactor design, a system for continuous skimming of the coolant surface was designed and installed as an addition to the device for control of reactor vessel level. The major components of the system are located on the south wall of the reactor equipment room with the exception of the skimmer unit, which is located in the reactor vessel shield.

The excess inventory of primary coolant that is maintained in the storage tank is pumped through a control valve and flow meter to a water-jet eductor or aspirator (see Fig. 29), where the liquid enters a pressure nozzle and produces a high-velocity jet. This jet action creates a vacuum in the pipe line connecting the eductor to the skimmer unit that is located in the reactor vessel, thus causing a flow of a mixture of liquid, gas, and scum (depending on reactor liquid level) up to the body of the eductor, where it is entrained by the pressurized liquid. Both the pressurized liquid and the mixture of liquid, gas, and scum are mixed in the throat of the eductor and are discharged against back pressure to a filter unit that will remove the entrained particles of aluminum and aluminum oxide. After passing through the filter unit, the liquid-gas mixture proceeds to the storage vessel, where separation of the gas and liquid takes place. To maintain a continuous skimming action, it is necessary to replace the same quantity of liquid to the reactor vessel that is removed by the eductor. This is accomplished by side streaming a certain amount of liquid from the pressure side of the skimmer pump, through an independent control valve and flow meter, and discharging it into the suction side of the primary-coolant circulating pumps.

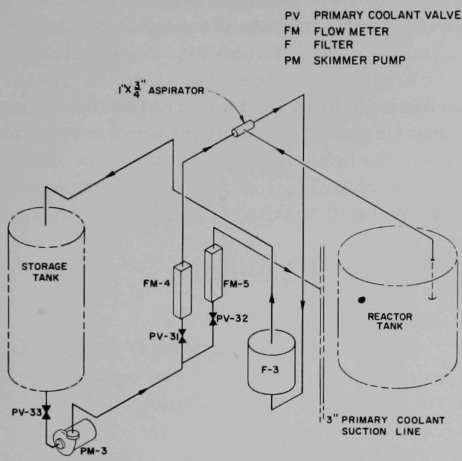

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Fig. 29. Schematic Diagram of "Janus" Skimmer System

Although the continuous skimming of the liquid surface film in the reactor vessel is to be considered important, it must be remembered that an equally important function of this system is to compensate automatically for temperature changes in the primary coolant system, and thus maintain a constant reactor liquid level.

(2) Flow Meters

The Schutle and Koerting parallel-mounted flow meters installed in the skimmer-level-control system are located adjacent to the pipe cavity on the south wall of the reactor equipment room.

These flow meters are of the full-view rotameter type, and are calibrated for 0-20 gpm (for a specific gravity of 1.0). The heavy-wall glass flow tubes and their Teflon seals are well protected by a safety shield composed of stainless steel and safety glass. As in the case of the cleanup-system flow meters, all metal parts that come in contact with the reactor coolant are 300 series stainless steel.

(3) Skimmer Pump

The skimmer-level-control system pump is a single-stage, standard-end suction, centrifugal type (see Table VI), horizontally mounted on a steel pedestal directly below the storage vessel at the south wall of the reactor equipment room. This monoblock motor-mounted pump is constructed of the same material and in the same manner as the primary coolant pump.

Table VI

SPECIFICATIONS FOR SKIMMER PUMP

Capacity	40 gpm
Total Head	40 ft
N.P.S.H.	10 ft
Impeller Diameter	$4\frac{1}{4}$ in.
Horsepower	1.5
Speed	3600 rpm
Voltage (3-phase, 60-cycle)	220/440
Pump Material	300 series stainless steel
Seal	Mechanical type E.A.

(4) Water-jet Eductor

The water-jet eductor located in the piping cavity at the southeast wall of the reactor equipment room is a Schutle and Koerting Type #264, size #1, and is totally constructed of Type 316 stainless steel.

A water-jet eductor of this design is used principally for liquid pumping and mixing operations. In this case, the eductor will allow both the pressurized liquid and the liquid and gas mixture removed from the reactor vessel by the skimmer unit to be thoroughly mixed in the throat of the eductor and to be discharged to the system filter. The streamlined body, with no pockets, permits the pressurized liquid to move straight through the eductor and reduces the possibility of solids in the suction liquid from collecting and clogging.

(5) Filter Unit

The filter unit incorporated in this system is located on the west wall of the piping cavity in the reactor equipment room.

This filter is expected to remove and trap at least 90 percent of the aluminum-aluminum oxide particles that are entrained in the liquid-gas mixture removed from the reactor vessel by the skimmer and eductor. To prevent the filter unit from becoming gas bound and thus limiting the area of filtering material and filter life, a special filter unit containing six (6) honeycomb filter tubes in a helium-gastight aluminum container was designed, constructed, and installed. Further details of this filter unit may be found on Drawing RO-1-1272-C.

During normal operation, the radioactivity level of the filter unit is expected to be rather high due to activation of the aluminum oxide particles. But the choice of location (in the piping cavity) and the addition of portable shielding blocks, if needed, will reduce activity levels to well below the accepted maximum for operating personnel.

(6) Skimmer Unit

The adjustable skimmer unit, located in the southeast quarter of the reactor vessel shield, is composed of essentially two principal parts: a 1-in.-diameter aluminum tube that is approximately 31 in. long, and a stainless steel annular shield plug that will contain the aluminum tube and the necessary seal mechanism for sealing the annular shield plug to both the aluminum tube and the reactor vessel shield.

When the reactor vessel coolant is at its normal operating level and when the skimmer unit is properly bolted down in place, the aluminum tube section of the skimmer will protrude through the shield just far enough to break the coolant-reflector surface.

Further details of the skimmer unit may be found on drawing RO-1-1284-B.

c. Helium Systems

(1) General Considerations

There are two helium systems associated with the "Janus" reactor which have the general primary function of supplying a controlled atmosphere of inert gas (helium) in their respective zones of the reactor. In particular, the system associated with the graphite reflector and thermalizer region of the reactor is called the graphite helium system. The other system, known as the reactor helium system, is contained within the reactor tank or vessel and the various branches of its primary coolant system. Both helium systems have a common supply consisting of helium gas cylinders and regulating valves feeding into the systems through an instrument panel, as indicated in Fig. 30 and Drawing No. RO-1-1281-B.

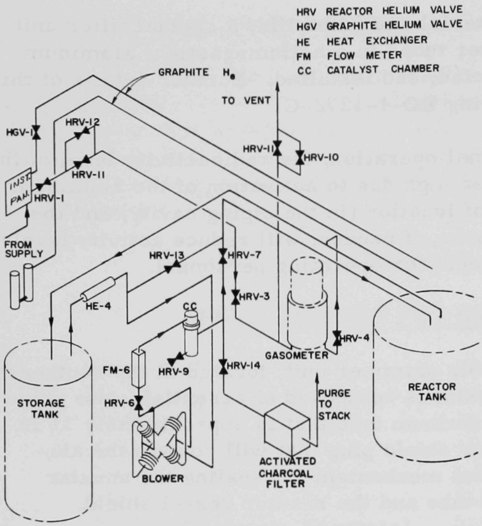

Fig. 30

Schematic Diagram of "Janus" Helium Systems

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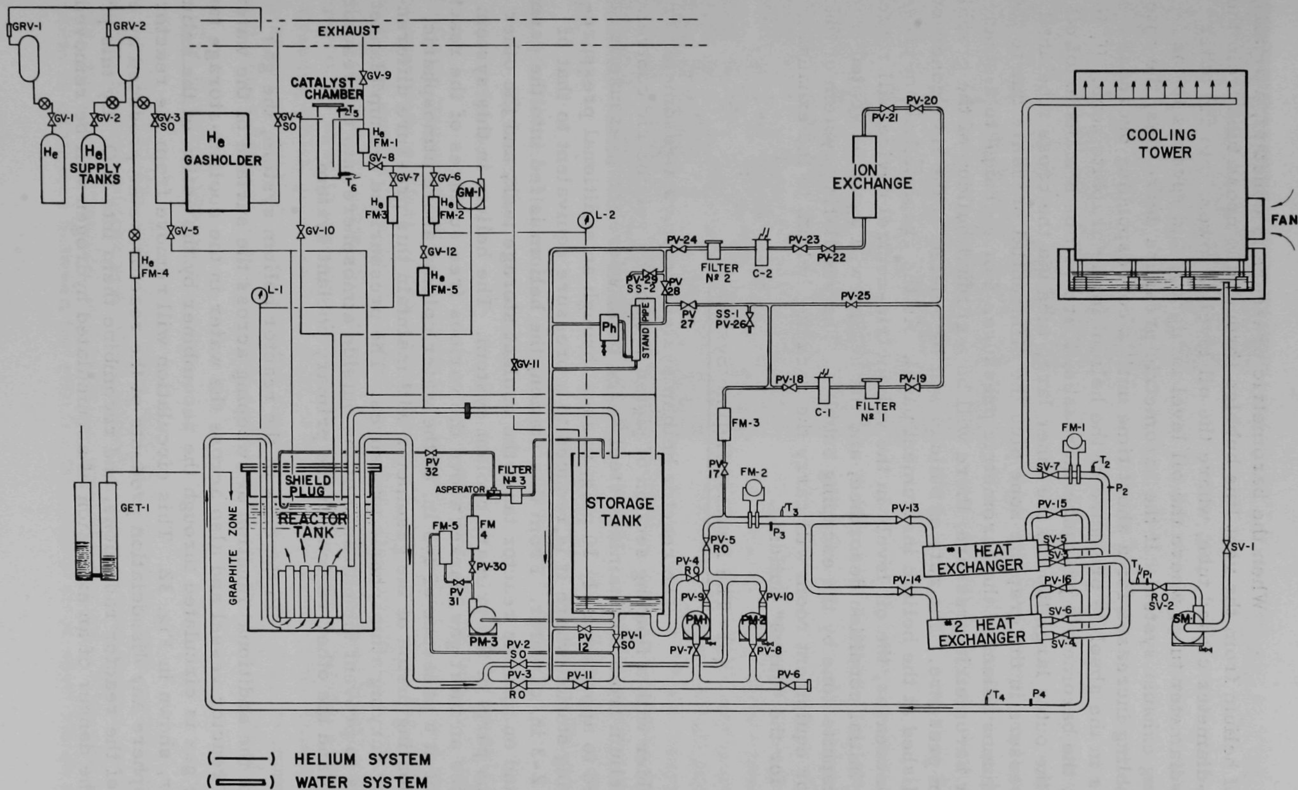
(2) The Graphite Helium System

The graphite helium supply is located on the north wall of the reactor equipment room. The helium from the high-pressure gas cylinder or cylinders is reduced in pressure by the regulator valve attached to the cylinder. One side of a branch line connection to the output of the above regulator directs the helium into a stainless steel surge tank equipped with a pressure-relief valve set for release at 10 psig. From the surge tank, the helium line leads to the instrument panel where the surge tank pressure is indicated and where another pressure-reducing station is located. This second regulator is adjusted to reduce the helium pressure to the equivalent of about 10-12 in. of water above atmospheric pressure. Pressure and flow meters on the instrument panel monitor the helium which is fed from the second pressure-reducing station to the graphite helium system indicated in Fig. 30. This helium is delivered directly through copper tubing to one side of the principal graphite zone of the reactor. The opposite side of this graphite zone is connected by a vent line to an oil-filled, manometer-type, volumetric-control device. This volumetric-control device is fabricated from two relatively large-diameter, vertical metal tubes joined together near their bottom ends by one or more small-ID cross tubes positioned horizontally in a vertical plane. This device is represented in Fig. 31 by the designation GET-1. It may also be observed in Fig. 30.



144-352

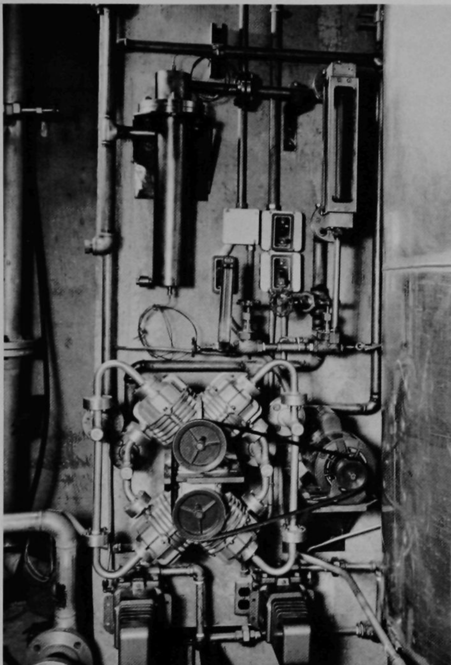
Fig. 31. Flow Diagram for "Janus" Water and Helium Systems

When the barometric pressure is constant, a small flow of helium from the vent line bubbles through the cross tube from the large-diameter closed tube, where the oil level is lower, into the other large-diameter tube, where the oil level is higher, and escapes to the building exhaust system. If the barometric pressure decreases, the rate of bubbling increases for a short time until a corresponding decrease occurs in the absolute pressure of the helium in the graphite zone. If, instead, the barometric pressure increases, there will be a transfer of oil from the outer large tube to the inner large tube via the cross tube until the pressure in the graphite zone plus the differential pressure due to the oil columns balances the barometric pressure. For a change to a steady, higher barometric pressure, there will be a gradual buildup of the graphite helium pressure. The rate of buildup will be related to the flow condition established at the helium instrument panel. As the graphite helium pressure increases, the oil levels in the volumetric-control device will return to the initial condition described, and the helium will again be vented from the graphite zone by the escaping bubbles. The ventilating system of the reactor equipment room will carry the escaping helium to the exhaust stack for the "Janus" building.

(3) The Reactor Helium System

The reactor helium system employs a gasometer or gasholder with a floating section of piston to provide volumetric control. The helium from the stainless steel surge tank, where the pressure is limited to approximately 10 psig, passes through an additional pressure-reducing station where it is reduced to a pressure equivalent to that of about 2-3 in. of water. From this station, the helium is fed into the gasometer and on into the reactor tank, the coolant storage tank, and the other various parts of the primary coolant system. The helium in this system supplies an inert gas blanket above the various free surfaces of the reactor coolant at a pressure of 2-3 in. of the water column above atmospheric. The floating piston of the gasometer will maintain this pressure differential for varying atmospheric pressures. The pressurized helium blanket serves to prevent the entrance of the outside atmosphere into the reactor vessel and the other regions of the primary coolant system.

In the case of the reactor helium system, the gas serves the additional function of sweeping across the surface of the water in the reactor vessel and also across the water in the coolant-storage tank as the gas is circulated through the recombiner by the action of the helium blower, shown in Fig. 32. This circulation will remove from the reactor atmosphere any dissociation products of the reactor water produced by effects of the reactor radiations, and recombine them into H_2O. By this process, the danger of an explosion of accumulated hydrogen will be removed.



144-289

Fig. 32. Helium Blower and Associated Parts of Reactor Helium System

d. Shield Cooling System

The steel shell, which serves as a boundary between the biological shield, and the graphite reflector and thermalizer of the reactor had an array of copper tubing secured to its outside bottom and wall surfaces before it was installed in the reactor structure. The arrangement of the copper tubing may be seen by looking at Fig. 7 and Fig. 8.

In the completed reactor, the copper tubing may be used to provide a shield cooling system if this is found desirable or possibly necessary in case operation is at a higher power level in the future than is presently considered to be the full power value. Copper tubing, carrying thermocouples, and some tubing into which thermocouples may later be inserted, were also installed on the bottom and walls of the steel shell.

The top shielding plug and cover of the reactor tank was similarly provided with a pattern of stainless steel tubing attached to the bottom inside surface of this shielding plug and tank cover. The ends of the tubing extend through the top plate of this cover where they are closed with threaded stainless pipe plugs. This array of stainless tubing may, if desired, be used to provide another section of the shield cooling system. A drawing which gives an indication of the arrangement of the shield cooling system installed in the reactor shield plug and cover may be found in the "Janus" drawing file by looking under Drawing No. RO-1-1050-F.

E. The Graphite Systems

The Reactor Tank Assembly with the contained core, moderator-coolant, neutron source and rabbit thimbles, coolant-circulation components, etc., is surrounded by a principal graphite system. This graphite system is contained between the reactor tank and a steel shell which forms the inner liner for the biological or radiation shield. This shield serves to isolate the reactor from the cells for acute and chronic irradiation. The steel shell is of welded construction with flange and gasket seals in those areas where attachments are made to the various associated components of the reactor systems. These attachments accommodate the neutron source and rabbit thimbles, the neutron windows of aluminum for transmission of neutrons to the converter plates, a neutron attenuator or flux adjuster, the top shielding plug and cover of the reactor tank, the nuclear instrumentation thimbles, and the helium lines used in supplying and circulating the gas atmosphere for the principal graphite system.

This arrangement of reactor tank and steel shell provides a gas-tight region in which the graphite used as neutron reflector and thermalizer may be maintained under a dry atmosphere of high percentage helium content. This graphite system contains two other smaller zones or regions. One of these auxiliary systems is located in the thermalizer or thermal column of the high-intensity face of the reactor. It consists of a graphite-filled, horizontal, rectangular re-entrant aluminum thimble, approximately 16 x 16 in. in cross section, extending inwardly about $25\frac{1}{2}$ in. from the thermal-column window toward the reactor core. The axis of this thimble lies on the horizontal centerline of the reactor core. The graphite blocks which fill this region are arranged to be removable without disturbing the remaining graphite of the reactor. A second auxiliary system is provided by a cavity situated in the graphite of the low-intensity side of the "Janus" Irradiation Facility. This cavity has the shape of a segment of a right circular hollow cylinder with its axis vertical. A line drawn from the center of the reactor core to the center of the neutron window at the low-intensity side of the reactor would be approximately normal to the inner and outer faces of this cavity.

Initially, both auxiliary systems will be filled with graphite. Later, if desired, the graphite may be removed from either or both auxiliary systems. This will permit locating certain specimens in a neutron flux of about 10^{11} n/(cm^2)(sec) in the high-intensity thermal column. In the second auxiliary system, a sealed aluminum tank of appropriate shape may be installed and filled with a dilute boric acid or other neutron-absorbing aqueous solution. This will increase the attenuation of the neutrons supplied to the converter of the low-intensity irradiation cell. Thus the ratio of intensities in the two irradiation cells may be adjusted by a factor of about 10^4 to 10^5. Provisions would be made in the shielding cover of the attenuator tank to circulate its gaseous atmosphere through a catalyst chamber to recombine the dissociation products of the contained solution.

Gamma-ray and neutron shielding is provided adjacent to the reactor tank above the principal graphite system by a $\frac{1}{4}$-in.-thick layer of boral and layers of lead totalling approximately 14 in. Further shielding of boral is used as a liner of the steel shell. The heavy shielding of lead and concrete is installed above and below the steel shell so that it is completely surrounded by massive biological shielding.

The principal graphite system which is contained in the steel shell of the reactor provides the base upon which the reactor tank rests. Further support is given to the reactor tank by six screw-type leveling jacks which are located between the stiffening gussets of the reactor tank. These leveling screws rest on a 5-in.-wide by a $\frac{3}{4}$-in.-thick partial ring of steel placed on the boral at the boundary between the graphite and the 14-in.-thick lead shielding which was mentioned above.

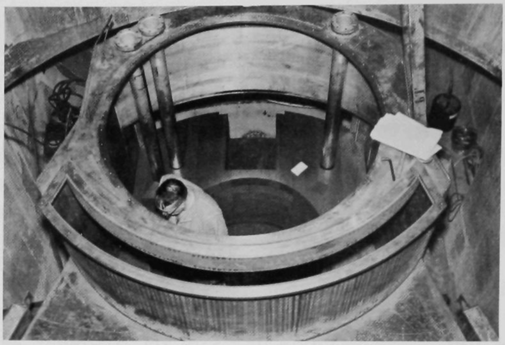
The relation of the various parts of the graphite systems to each other and to the components mentioned in Sec. E are shown by a series of photographs: Figs. 9, 20, 33, 34, 35, 36, and 37.

Additional details of the graphite systems may be obtained by reference to Fig. 12, Drawing No. RO-1-1041-E, other associated drawings of the "Janus" Drawing File, and the appropriate bills of materials.

F. The Rabbit Installation

Provision has been made in the design of the "Janus" Irradiation Facility for insertion of small samples to a region near the core of the reactor and their subsequent removal without shutdown of the reactor. The thermal-neutron flux in this region is expected to be of the order of 10^{11} n/(cm^2)(sec).

Rapid insertion and removal of the samples is to be accomplished pneumatically. This installation, referred to as a Pneumatic Rabbit Facility, is to be operated at pressures below atmospheric. The samples will be impelled into the neutron-flux region by connecting briefly one end of a hairpin or U-shaped conduit to a vacuum reservoir while the rabbit sample in a lightweight container is resting in the other end of the U-shaped tube, or its extension, which is open to the atmosphere. The pressure difference will drive the sample into the tube until it reaches a mechanical stop. A continuing pressure difference provided by a ventilation system will hold the sample against the stop in the neutron-flux region until it is desired to remove the sample. For removal of the sample, the connections to the ends of the U-shaped conduit are to be reversed and the sample driven from the mechanical stop toward the end then connected to the vacuum reservoir. An attachment at this end, known as a loading and unloading station or breech, will catch the sample or divert it to another receiver, from which it may be removed and utilized. The connections and reversal of connections to the vacuum reservoir and the surrounding atmosphere are to be accomplished by solenoid-operated valves. The partial vacuum of the reservoir will be maintained by a motor-driven Kinney KC-5 mechanical vacuum pump of 5-cfm free air-displacement capacity (see Table VII).



144-162

Fig. 33. Instrument Thimbles and Thermal-column Cavity Locations in Principal Graphite System

144-166

Fig. 34. Location of Attenuator Cavity in Principal Graphite System

112-1205

Fig. 35. High-intensity Thermalizer and Irradiation Cavity with Neutron Converter Plate Down

112-1201

Fig. 36. Reactor Tank Partly Inserted in Principal Graphite System

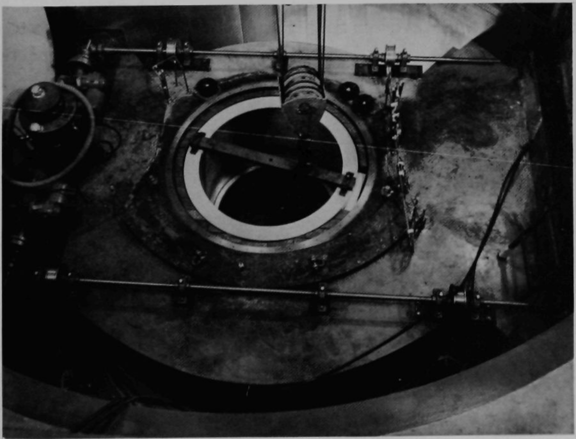


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Fig. 37. Reactor Tank Resting on Supports of Principal Graphite Systems

Table VII

SPECIFICATIONS FOR RABBIT FACILITY VACUUM PUMP

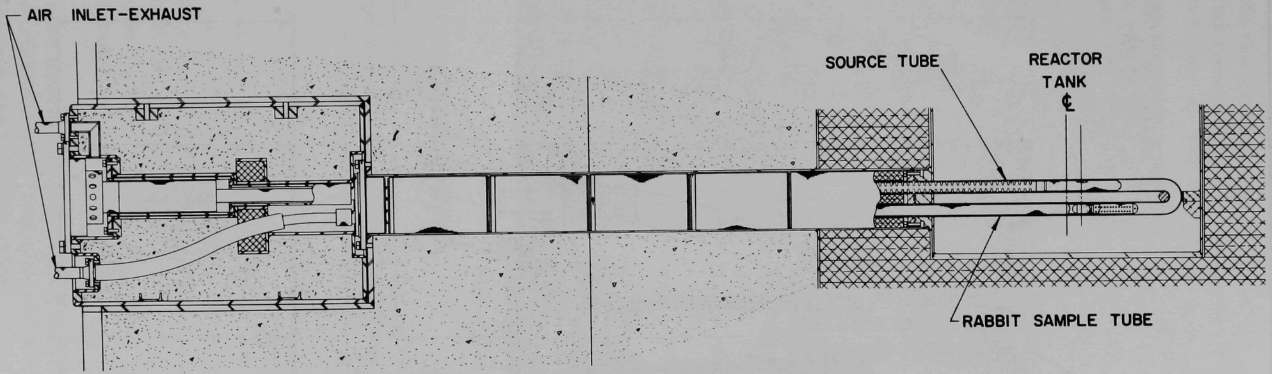
Free Air Displacement	5 cfm
Pump, rpm	630
Oil Capacity	3 pt
Shaft Diameter	3/4 in.
Motor Horsepower	1/3
Motor, rpm	1800
Net Weight	140 lb

The volume of the vacuum reservoir (about 5 ft^3) will be sufficient to allow successive rabbit insertions and removals at relatively frequent intervals without undue change of the pressure differential which drives the samples. Manual insertion and removal of the rabbit samples may be employed, in which case the buttons controlling the valve operations are to be depressed by the operator of the facility with whatever timing is desired. The facility is also to be equipped with an automatic timer which may be set for a desired irradiation time.

After the sample has been put in the loading station, a button is depressed by the operator and the sample is inserted as the timer is started. When the selected irradiation time has been reached, the timer will automatically remove the sample to the rabbit station.

A somewhat remote counting room and rabbit laboratory is to be added to the "Janus" reactor building on the first floor near the reactor control center. When this laboratory is completed, insertion and removal of rabbit samples may be accomplished at a station in that room. The extension conduit leading from the present location in the preparation room for the low-dose irradiation cell to the rabbit laboratory will be shielded against radiation leakage as may be required.

The U-tube, which is welded into the reactor tank and which with its extensions reaches through the external shielding of the "Janus" reactor to the preparation room for the low-dose irradiation cell, serves also to house the startup neutron source for the reactor. The U-tube and extensions lie horizontally with the two arms in a vertical plane, as shown by Figs. 9, 10, 17, 18, and 38. The bottom arm houses the liner which provides the path and mechanical stop for the rabbit samples within the reactor tank. Perforations in the walls of this liner will permit the flow of air required to move the rabbit sample and to provide ventilation through the arms of the U-tube. A gentle S-curve of the lower arm occurs in the removable external shielding block of the U-tube assembly, as shown in Fig. 38 and Fig. 39. This offset will serve to shield against radiation leakage



144-264

Fig. 38. Partial Vertical Section through the "Janus" Neutron Startup Source and Rabbit Facility

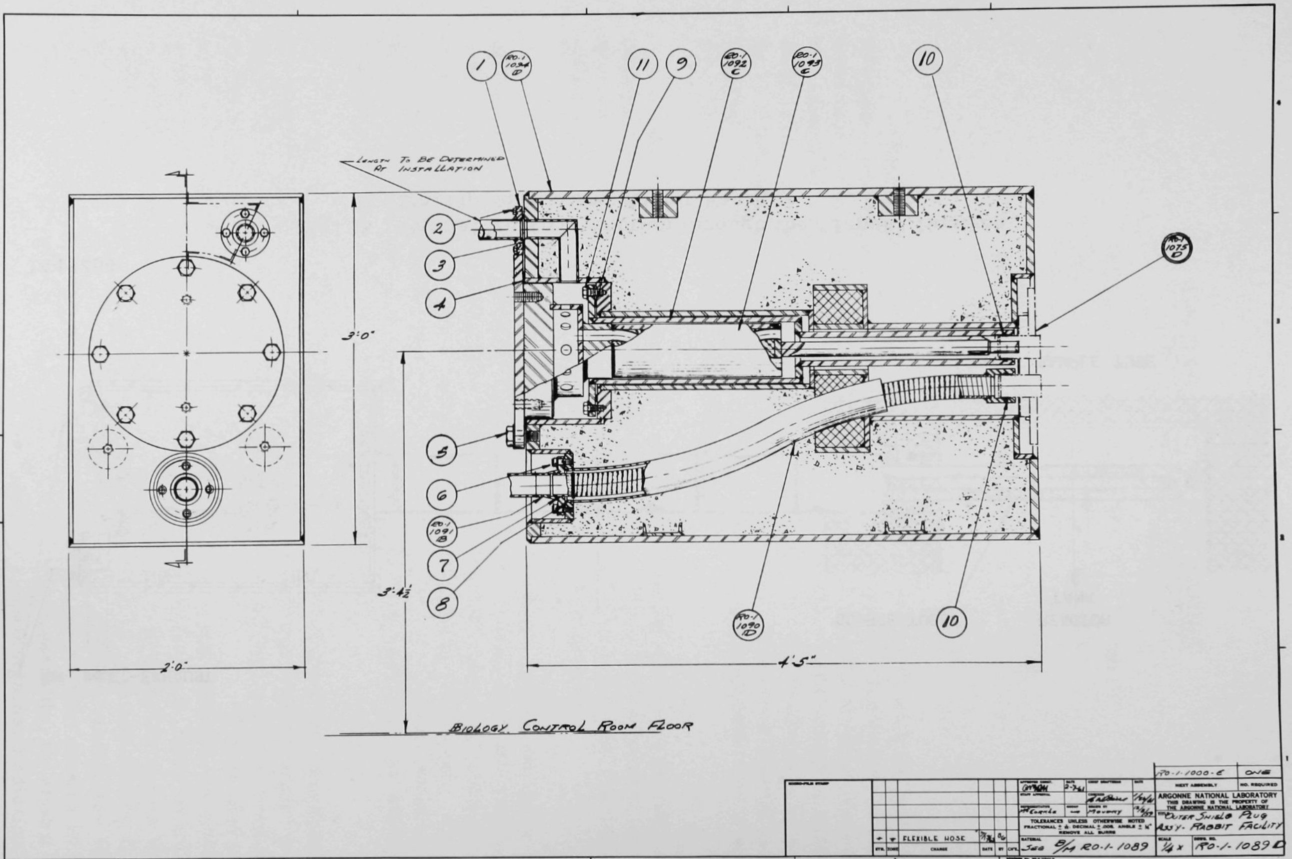
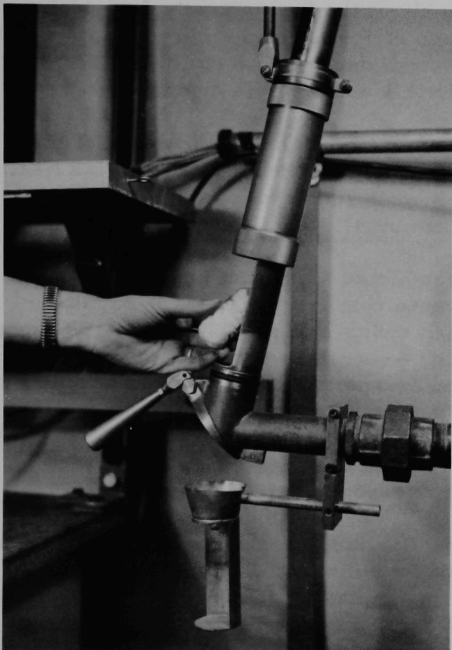


Fig. 39. Outer Shield Plug Assembly of Rabbit Facility

from the reactor into the preparation room while providing an unobstructed path for insertion and removal of the rabbit samples. The axis of the path in the top arm is straight, but the diameter is varied stepwise. The arrangement enables straight-line insertion of the neutron-irradiated antimony section into the beryllium portion of the neutron-source tube. Subsequent installation of the stepped shielding plug then seals the system against radiation leakage and directs the air flow to the building exhaust system for ventilation of the U-tube, and to the rabbit propelling system for insertion and removal of the samples. Additional details of the arrangement for accommodating both the startup source and rabbit samples may be found in Figs. 19, 38, and 39, along with their indicated detail drawings and the associated bills of materials.



150-167

Fig. 40. Rabbit Facility Loading and Unloading Station

The station intended for loading or unloading rabbit samples is shown in Fig. 40, which is a photograph of its installation at the CP-5 reactor where it was previously used.

A construction layout of the proposed piping extensions to the U-tube and of the associated equipment for the rabbit facility is given in Drawing No. RO-1-1221-E.

G. The Converter Assemblies

Neutron-converter assemblies are installed outside of the reactor proper, beyond the neutron windows for the high- and low-intensity faces of the reactor. There are sufficient thicknesses of graphite and water between the neutron windows and the reactor core that motion of the converters relative to the neutron windows will have almost inappreciable effect(3) upon the neutron chain reaction of the "Janus" irradiation facility.

Both converter assemblies are fabricated from similar elements of uranium highly enriched in U^{235} and alloyed in aluminum, as mentioned earlier. These elements are 1.27 cm thick, 10 cm wide, and 97.8 cm long.

Each of these elemental strips contains approximately 320 g of the 93% U^{235} enriched uranium alloyed in 1100 aluminum.

The neutron-converter assembly at the low-intensity face of the reactor is composed of 30 of the above strips to form a curved plate which is approximately 1.27 cm thick, 300 cm wide, and 97.8 cm high. The total amount of highly enriched uranium in this assembly is about 9,600 g.

The converter assembly for use at the high-intensity face of the reactor contains about 6,100 g of the highly enriched uranium. This fissile material is supplied by 19 of the elemental strips which form a curved plate approximately 1.27 cm by 190 cm by 97.8 cm.

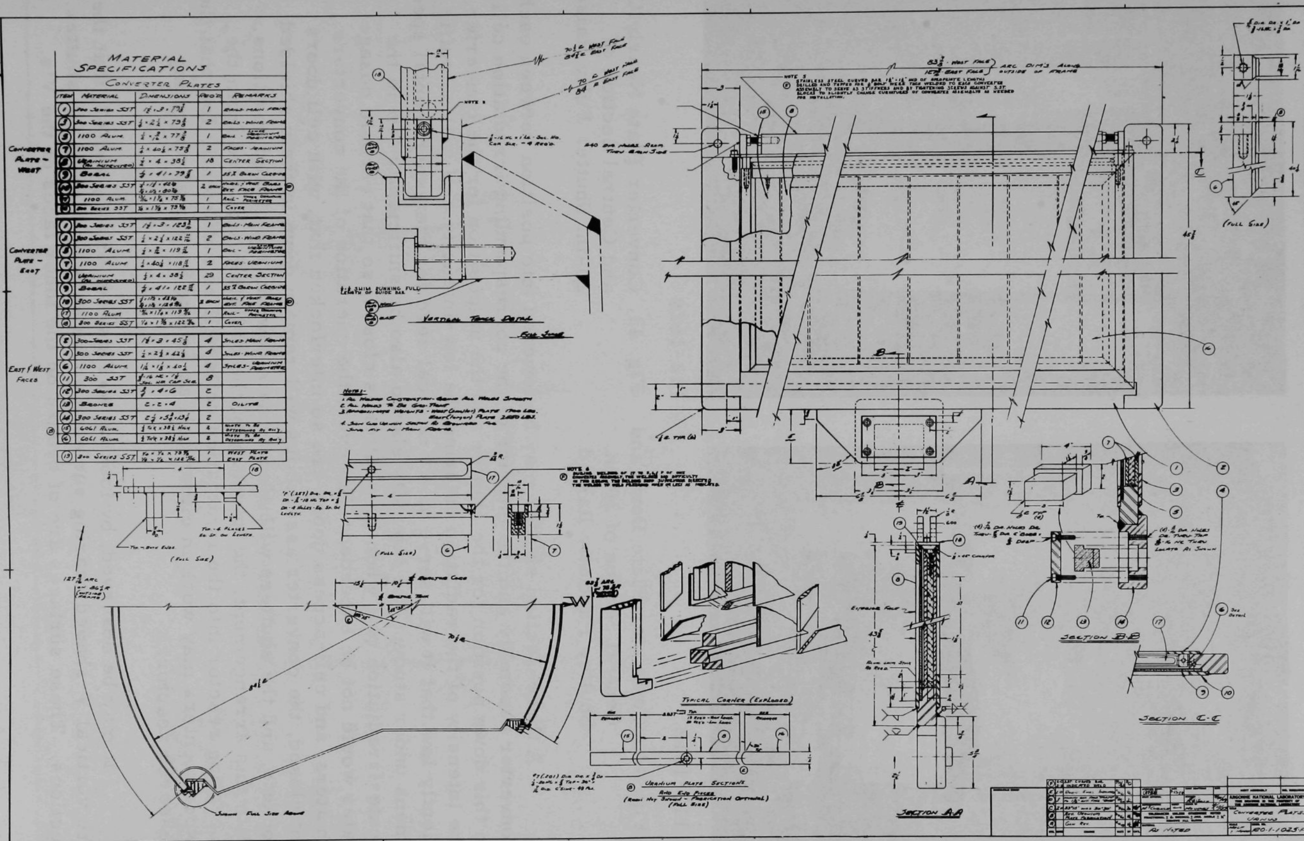
Each converter plate is encased in an aluminum shell which is welded gastight. The aluminum-encased converter plates are each inserted in stainless steel frames which support them. The convex surfaces of the converter shells are covered by $\frac{1}{4}$-in.-thick sheets of boral which are also held within the stainless steel frames of the converter assemblies. Details of the converter assemblies are supplied in Fig. 41 along with the corresponding bill of materials.

The converter assemblies are arranged to be run up or down in bronze-lined guides which permit them to be positioned directly outside of the neutron windows of their respective faces of the reactor or in shielded pockets which are below the levels of the windows. The mechanisms by which the converter assemblies are manipulated are described in another section of this manual. The general arrangement of the converter assemblies and the other components of the "Janus" Irradiation Facility is depicted in Fig. 9 and Fig. 11.

When the neutron-converter assembly for the high-intensity face of the "Janus" reactor is positioned directly before the neutron window of that face with the reactor operating at such a power level that the thermal-neutron flux impinging on the converter has the average value of 2×10^{10} n/(cm^2)(sec), the dosage of fission neutrons directed toward the acute-irradiation cell is expected to be approximately 10^6 rads/week, as discussed in Sec. III of this report.

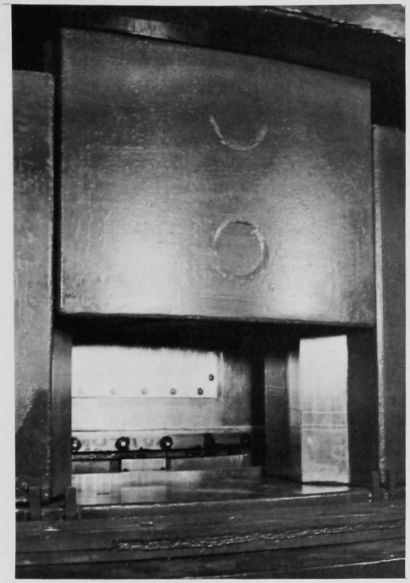
H. The Neutron Shutters

Neutron shutters are arranged for positioning between the neutron-converter assemblies and the interior of the irradiation cells, as indicated in Figs. 9, 11, 42, and 43. These shutters are each massive, three-sectioned arrangements of neutron-moderating-and-absorbing materials contained in welded steel cases. These shutters are also effective for absorbing gamma rays coming from the reactor proper and the converter assemblies.



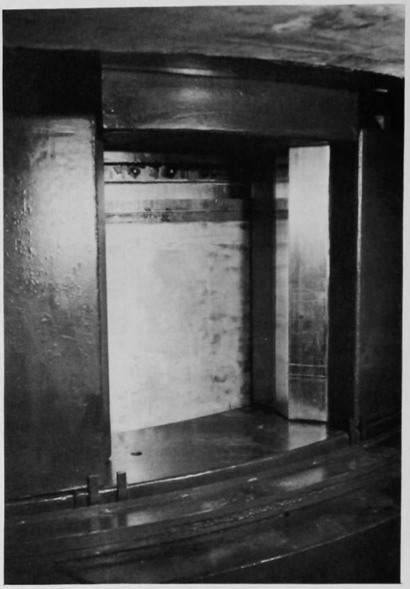
144-298

Fig. 41. Converter Plates for "Janus"



112-1612

Fig. 42. Converter Plate Down and Central Section of 20-in. Shutter Partially Raised

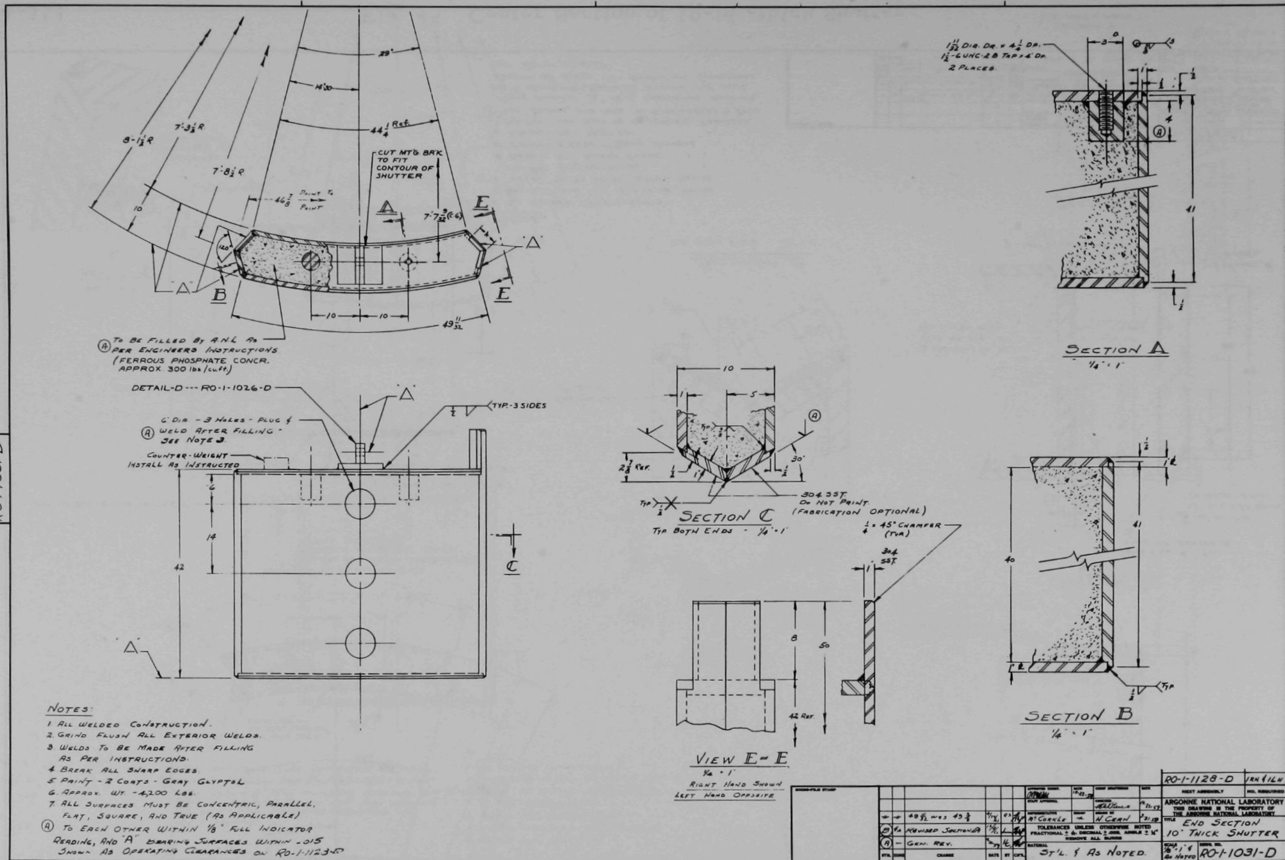


112-1628

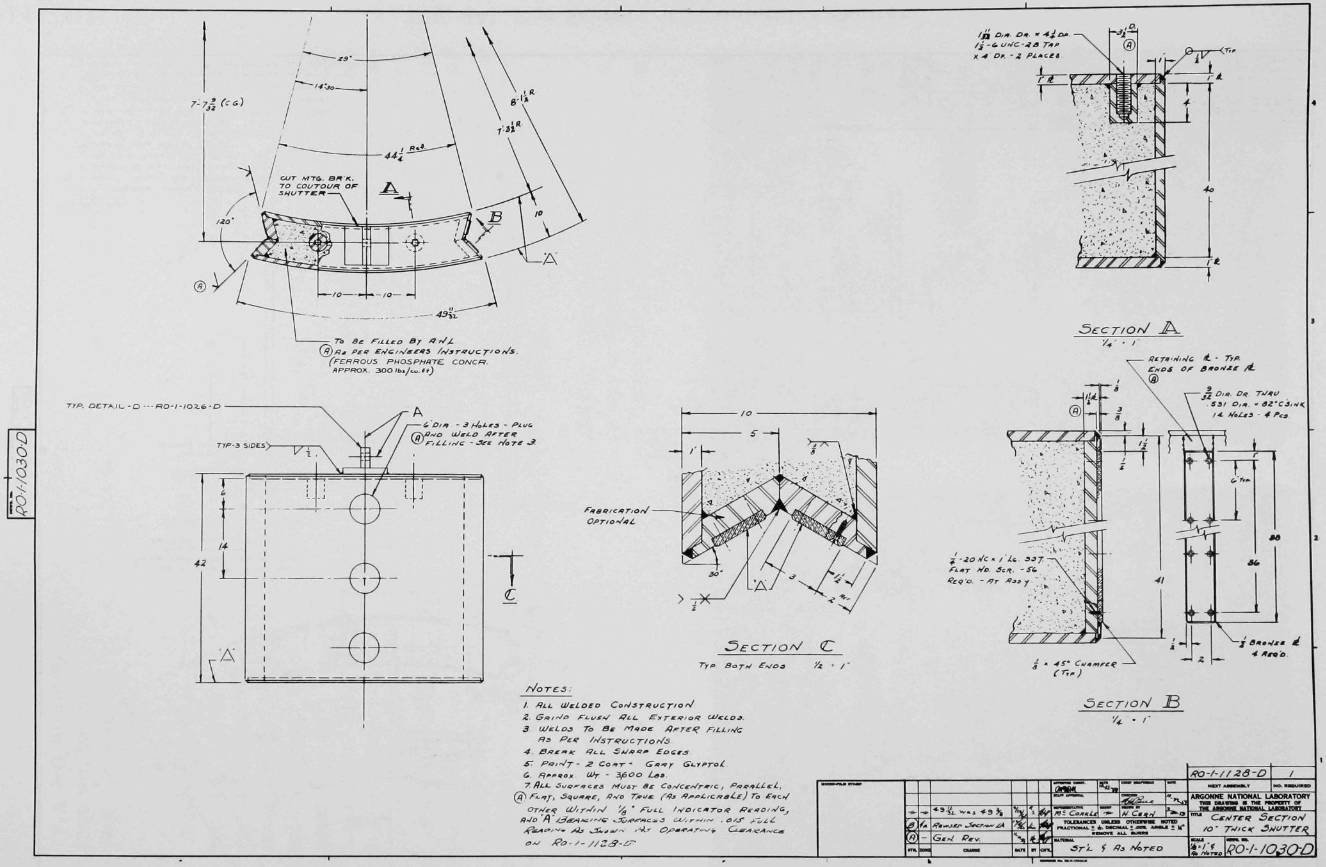
Fig. 43. Converter Plate Nearly Up and Central Section of 20-in. Shutter Fully Raised

A three-section shutter may be lowered into position between each converter assembly and the interior of the corresponding irradiation cell. In this down position for the shutter and the up position for the converter, the intensity of the radiation entering the low-intensity cell will be sufficiently low that it will serve as a practical zero for the experimental specimens under study. The intensity should also be sufficiently low in the acute-irradiation cell when its shutter is closed, so that chronic dosage rates would not be exceeded. However, the operation of the converters, shutters, and cell-access doors are so interlocked that, with cell doors not closed, the converter assemblies will remain down in their shielded pockets, and the shutters will also remain down in the closed positions. With this arrangement, the intensity of the radiation admitted from the operating reactor into the irradiation cells will be sufficiently low that the experimenters may work in either cell as around a normal operating research reactor.

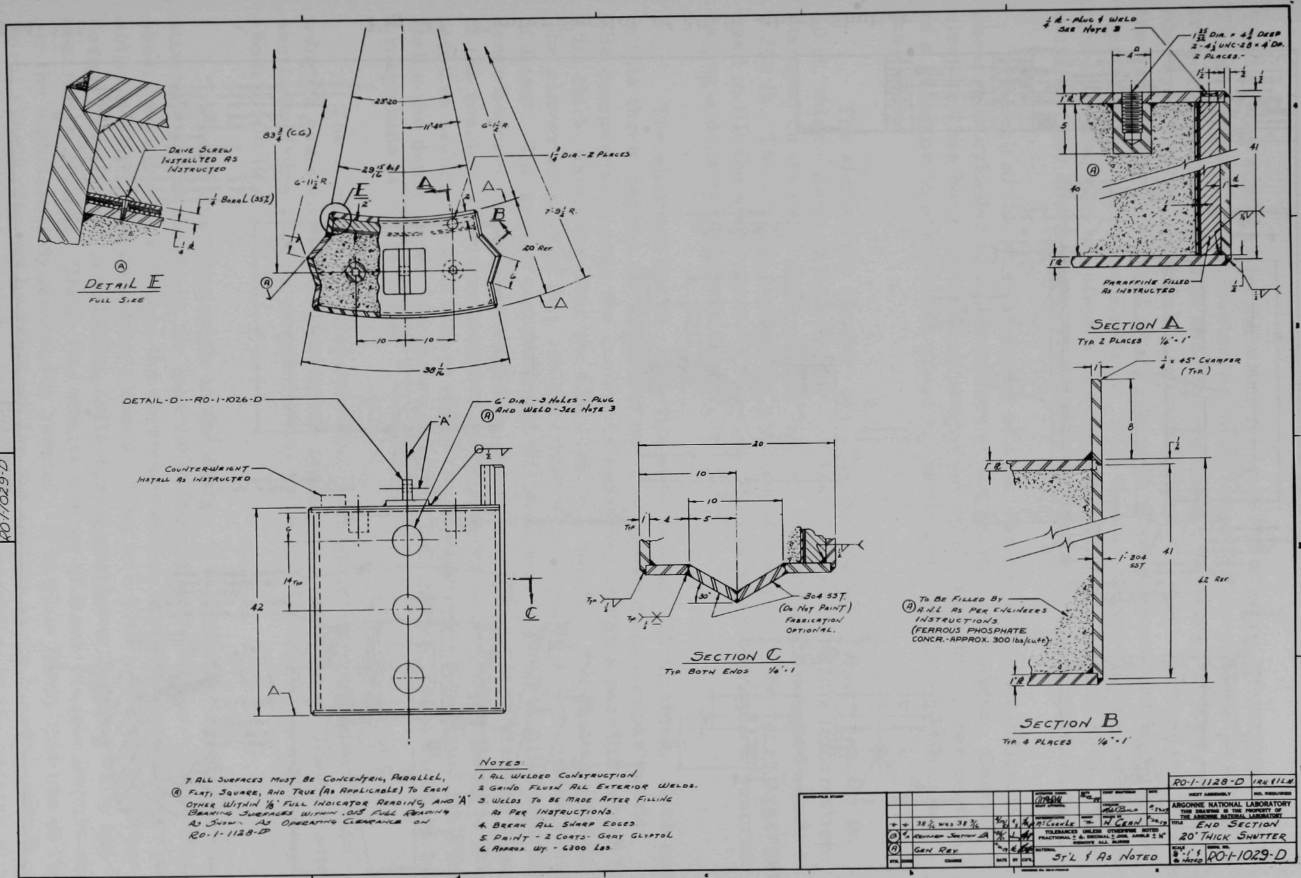
It may be observed, by looking at Figs. 44, 45, 46, and 47, that there are vertical V-shaped bearing surfaces at the ends of each of the shutter sections. These surfaces are of bronze on the inner faces of the V's.



144-311 Fig. 44. End Section of 10-in.-thick Shutter



144-313 Fig. 45. Center Section of 10-in.-thick Shutter



144-308

Fig. 46. End Section of 20-in.-thick Shutter

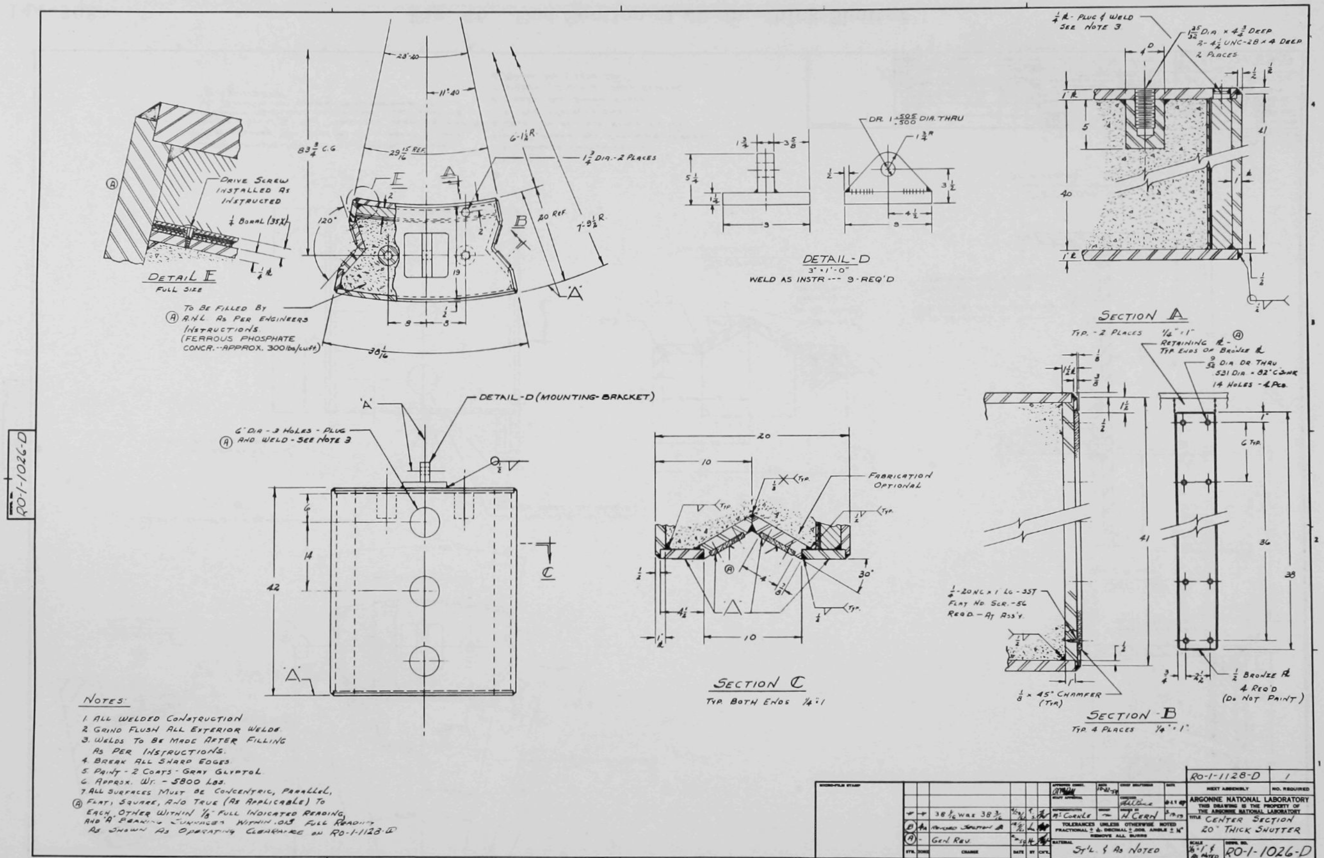


Fig. 47. Center Section of 20-in.-thick Shutter

The bearing surfaces on the outer faces of the V's are of stainless steel. The selection of these dissimilar metals was for the purpose of reducing friction and removing the need for lubricated surfaces. It may also be observed that the stainless steel portions of the outer shutters, which form the guides for the central shutter in each shutter group, extend above the tops of their respective shutters. With this arrangement, the central section is guided if it is raised while the outer shutters remain down. Other details of the shutters are also shown by the figures just referred to.

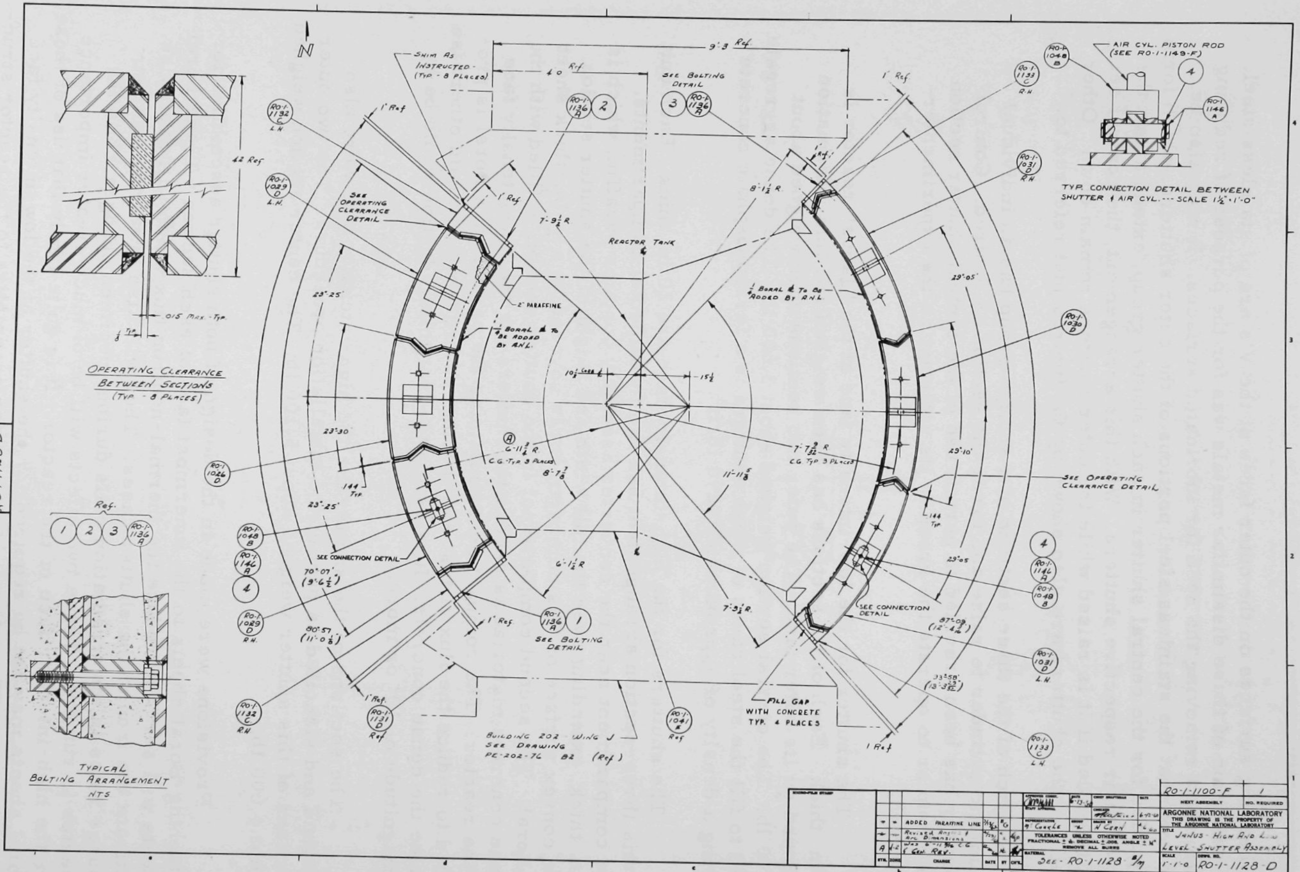
Each of the three sections of a shutter group has an individual pneumatic cylinder to raise and lower the section as desired. Control circuitry has been provided to permit use of the central shutter section of a group or to operate the group in its entirety, as the experimenter may wish.

The shutter for the low-intensity face of the "Janus" reactor is 10 in. thick. Each of its sections has been weighed and this information stamped on its outer face. The outer two sections each weighed about 4,200 lb. The central section weighed about 3,600 lb. The dense aggregate used to fill the steel cases of these shutters is a ferrophosphate concrete having a density of approximately 290 lb/ft^3.

The shutters for the high-intensity face are 20 in. thick. Each unit in this three-section arrangement has two fundamental compartments. The compartment near the converter assembly contains paraffin, which is 2 in. thick, extending over the full width and height of the shutter section. The convex surface of this compartment is covered by a $\frac{1}{4}$-in.-thick sheet of Boral. The second compartment in the shutter section is filled with the dense concrete material as used in the shutters for the low-intensity face of the reactor. The compartment containing the paraffin and Boral is provided to reduce the flux of fast and thermal neutrons which would otherwise strike the dense concrete. It is estimated that this reduction would be by a magnitude of 10^3 or more.

The sections of the shutter for the high-intensity face were also weighed and stenciled as part of the installation procedure. The two outer sections of this shutter weighed about 5,100 lb. The center section weighed about 4,600 lb.

Provisions were made in the design of both shutter assemblies for attaching Boral sheets to the innermost face of each section. These Boral sheets will serve to reduce the thermal-neutron flux which will otherwise activate the iron of the shutter cases. They will also lower the neutron-dosage rates in the irradiation cells during specimen changes while the reactor is running. These two effects will be of much greater importance for the high-intensity face of the reactor. It is quite likely that use of these Boral sheets may not be required for the shutter at the low-intensity face of the reactor. The relation of the shutter assemblies to the reactor structure may be observed in Fig. 48.



144-302

Fig. 48. "Janus" High- and Low-level Shutter Assembly

When the shutters are in their closed positions, they will rest upon massive pedestals. The shutter pedestals for both the low-intensity and the high-intensity faces of the reactor are formed from interlocking, steel-encased concrete sections. The details of fabrication and installation of these pedestals may be found in Fig. 49 and Fig. 50.

I. Drive Mechanisms

The function of providing specific radiation dosages to selected specimens arranged in the irradiation cells of the "Janus" facility is accomplished primarily by three types of control devices. Each of these categories of control is manipulated through drive mechanisms which are remotely operated from the control center for the reactor.

1. Shutter Drives

At the reactor side of each irradiation cell is a neutron and gamma-ray shutter which serves essentially to isolate the irradiation cell from the reactor when the shutter is closed (that is, interposed) between the reactor and the curved lead wall at the reactor side of the cell. Details of the construction of the lead walls and the shutters have been given in previous sections of this manual.

The shutters are moved upward from the closed position to open the neutron aperture between the reactor face and its respective irradiation cell. Since each shutter is composed of three sections, the use of individual drives for each shutter section was considered to be desirable. It was convenient also to have the same basic unit for all the shutter drives, namely, a pneumatic cylinder and piston. All pneumatic cylinders are similarly mounted in shielding and structural members above the shutters at the top of the reactor. Individuality of the mounting arrangements was made necessary, however, because of the geometrical shape of the reactor and the different dimensions of the several shutter sections. Some of these details may be made evident by reference to Fig. 11.

a. Air Cylinders

The pneumatic cylinders which lift and lower the individual sections of the shutters are connected to the shutter sections by a chrome-plated stem or piston rod which extends from the bottom of the vertically mounted cylinder. A clevis on the exposed end of the piston rod is secured to an attaching eye welded to the top of the corresponding shutter section. The attachment is completed by a pin inserted through the clevis and eye when the drive mechanism is installed. The process of installation consists of attaching shims to the bottom of a particular

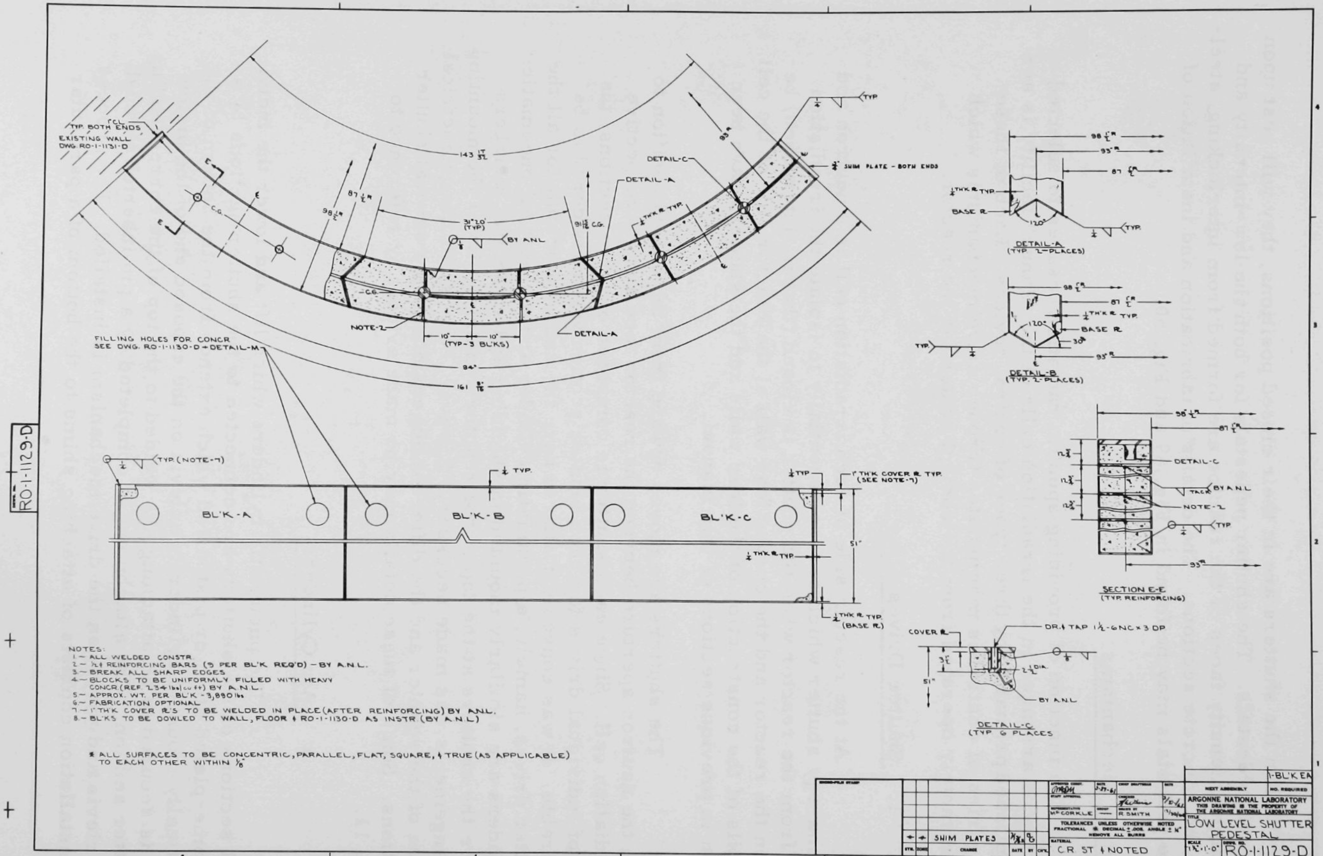
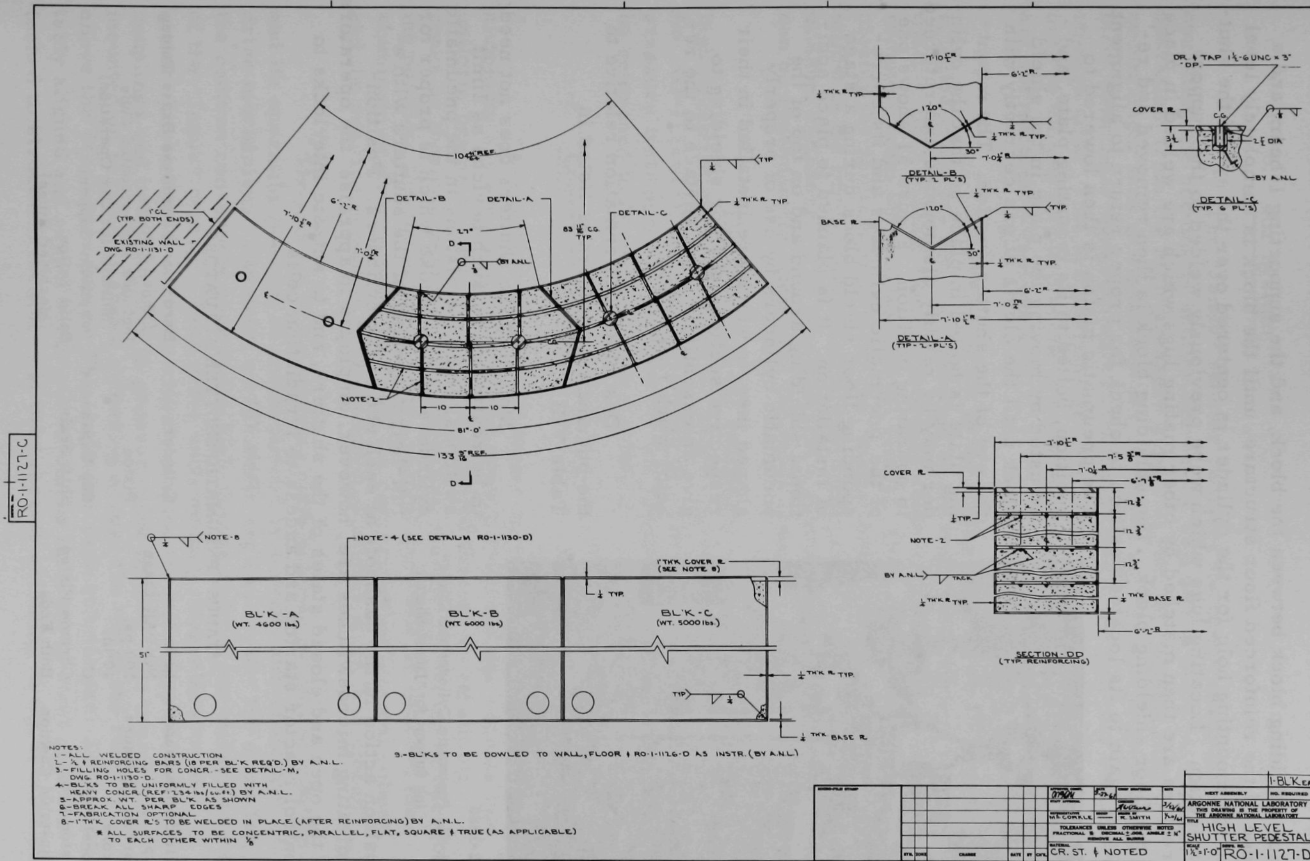


Fig. 49. Low-level Shutter Pedestal



144-299

Fig. 50. High-level Shutter Pedestal

floor shielding block between the block, and the supporting I-beam and a ledge of the reinforced floor structure, until the block is completely level and the mounting hole for the cylinder is centered over the eye of the shutter section. Locating lugs which were previously welded to the support structure are then matched by other mating lugs which are welded in place to the floor shielding block. The shielding block is then removed and returned again to its located position to check for proper return to alignment.

112-1630

Fig. 51. Pneumatic Cylinder and Shielding Support for "Janus" Shutter

The pneumatic piston is then lowered to position, bolted to its mounting plate, and adjusted by moving the plate in the shield block until the clevis aligns correctly with the eye of the shutter section. The mounting plate is bolted in place so that the cylinder may be readily dismounted and returned to operating position. Figure 51 shows one of the pneumatic cylinders and its corresponding floor shield block during a stage of installation. It is planned to place additional shielding around and on top of the pneumatic cylinders by use of properly shaped inserts which are installed in their respective sections of floor shielding to give an essentially level surface to the reactor work room floor.

Descriptive information relative to the pneumatic cylinders is listed in Table VIII.

Motion of the shutters does not need to be restricted by such devices as limit switches, since the pistons in the pneumatic cylinders have a stroke which is proper for full-height opening of the shutters with a cushion action in the dashpots at each end of the cylinders. Position-indicating microswitches are, however, employed to appraise the operators of the open and closed states of the shutters, and to actuate interlocks to control reactor startup and access to irradiation cells.

Table VIII

"JANUS" PNEUMATIC SHUTTER ACTUATORS

Cylinder Diameter	12 in.	Cylinder	Hard-drawn Seamless Brass Tubing (Honed Finish)
Type	NO PAK Class 1		
Working Pressure	100 psi	Piston	Includes Teflon-coated Cups (Suitable for Dry Operation)
Stroke	40 in.		
Model	C	Cup Expanders	Beryllium-Copper
Piston Rod	Chrome Plated	Shaft Seals	Solid Teflon (Machined Rings)
Adjustable Cushion	Both Ends		

b. Air System

The "Janus" reactor receives its compressed air for operating the pneumatic shutter drives, as well as for other instrument operation, from the high-pressure supply system of Building 202. An accumulator tank is mounted at the ceiling of the "Janus" reactor equipment room near the south wall of the room, above the primary coolant-storage tank. This accumulator serves to prevent any large pressure drop in the air supplied to the pneumatic cylinders if all the cylinders are operated simultaneously.

Admission of air to the lifting sides of the pistons in the selected cylinders and the discharge of air from the cylinders to the ventilating stack system are controlled by solenoid-actuated valves operated remotely from the reactor control center. The speed of opening and closing the shutters is determined, within limits, by the pressure maintained in the accumulator tank and by orifices in the air lines to the individual cylinders. It is expected that a shutter opening or closing time can be reproducibly attained in the range from 10 to 20 sec.

The details of the equipment and piping layouts of the high-pressure air system for the shutter drives are given in Drawings No. RO-1-1187-D and No. RO-1-1188-D. The arrangements of the low-pressure instrument air system for the "Janus" reactor may be observed by reference to Drawing No. RO-1-1246-C.

2. Converter Drives

Large curved plates of highly enriched uranium alloyed in aluminum are arranged to be moved upward from storage pockets into uniform beams of thermal neutrons supplied through thermalizing zones or thermal columns of the operating reactor. In the up or operating position, the converter at either reactor face will lie between the aluminum neutron-window covering the corresponding thermal column and the position occupied by the respective shutter when it is closed.

The moving of a converter plate between its stored position and its operating position is accomplished by a drum-and-cable type of drive mechanism. The drive mechanisms are essentially the same for the neutron converters used at the high-dosage and the low-dosage faces of the "Janus" reactor. Both drive units employ integrally mounted, motor-driven speed reducers closely coupled through adjustable slip couplings and beveled gears to grooved cable drums. The drums are mounted on horizontal shafts extending across the top of the reactor above the respective faces. The shafts for each reactor face are similarly aligned and supported by pillow blocks fastened to steel plates attached to structural members of the concrete shielding of the reactor and made entirely rigid by the concrete poured around them. Since it was desirable to have the motor drives mounted at the south side of the reactor structure, the drives are of a right-hand and a left-hand arrangement. The cables employed to wrap around the drums and attach to the shackles on the converter plates are $\frac{1}{4}$-in.-diameter stainless steel rope with a swaged anchoring attachment at one end of each cable. This swaged fitting engages in a recess in the drum for each respective cable. The other end of each cable is fastened to a locking turnbuckle which carries an eye that is pinned to the shackle at one side or the other of each converter plate. The turnbuckles are adjusted to level the converter plates so they will move smoothly in the guides at the sides of the neutron windows. When these adjustments are correct, the turnbuckles are locked to maintain continued smooth operation. Limit switches actuated by motion of the converter plates serve to indicate positions of the converters, to limit their motions to the prescribed magnitudes, and to trigger interlocks associated with operation of the reactor and the access doors to the irradiation cells.

When in their down positions, the converter plates are suspended by the attached cables within a few centimeters of a shock-absorbing layer of Styrofoam which was poured at the bottom of the storage pocket. This shock absorber is provided as a protection for the converters if, by some failure, the converters might be dropped against the bottom of the pockets.

The arrangement of the converter drive mechanisms at the top of the reactor may be seen in Fig. 37. Additional details concerning the converters and their drives may be found in Drawing No. RO-1-1101-D and its associated bill of materials. Data relative to the integral motor-gear reducer are listed in Table IX.

Table IX

GEAR MOTOR

Model	R-13
Volts	220/440
Amperes	1.6/.8
Ratio	900:1
Input, rpm	1725
Input, hp	1/2
Output, rpm	1.9
Output Torque	6288 in.-lb

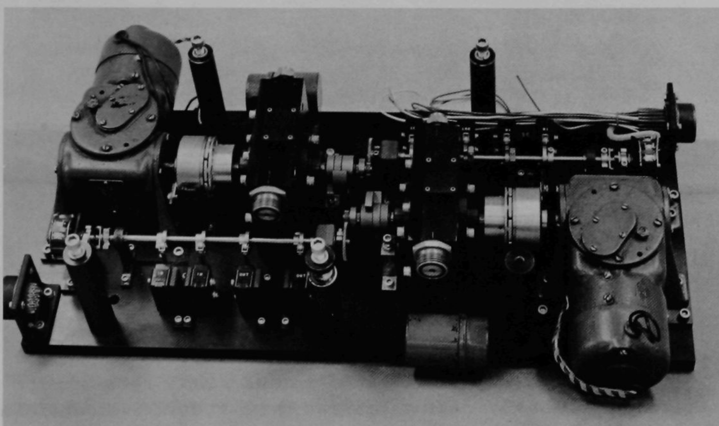
3. Control-rod Drives

The "Janus" reactor is equipped with a total of seven control rods. Six, intended to serve as shim-safety rods, move along vertical paths in the reactor core at locations mentioned in Sec. V-B of this manual. The seventh control rod is arranged to be driven up or down in a vertical path along the axis of the reactor core, but it is not capable of being dropped as a safety rod. This rod which may be moved in precisely indicated increments of position is intended to serve as a regulating or fine control rod.

There are five drive mechanisms associated with the seven control rods. Three individual drives operate, respectively, the regulating rod and one shim-safety rod in each row of three mentioned in Sec. V-B.

Two additional drives each operate two shim-safety rods as a gang in each row. The drive components were supplied by the Teleflex Corporation and were modified in the ANL shops to provide the single- and gang-drive arrangements.

Each shim-safety rod drive mechanism is equipped with a reversible motor and an integrally mounted speed reducer. The output shaft of the speed reducer is in-line with a magnetic clutch, an encased Teleflex Drive pinion, and a rotating mechanical stop. An offset shaft is driven by a small pinion at the end of the rotating mechanical stop. This offset shaft carries cams which actuate electrical position-indicating and limit switches. At the end of the offset shaft, opposite to the pinion drive gear, a potentiometer is actuated by the shaft. The potentiometer provides the analog signal for indicating the position of a shim-safety rod between the in and out limit positions. These various details may be observed in Fig. 52, which shows the arrangement of two drive mechanisms on a single mounting plate to operate the three shim-safety rods in one of the rows mentioned above.

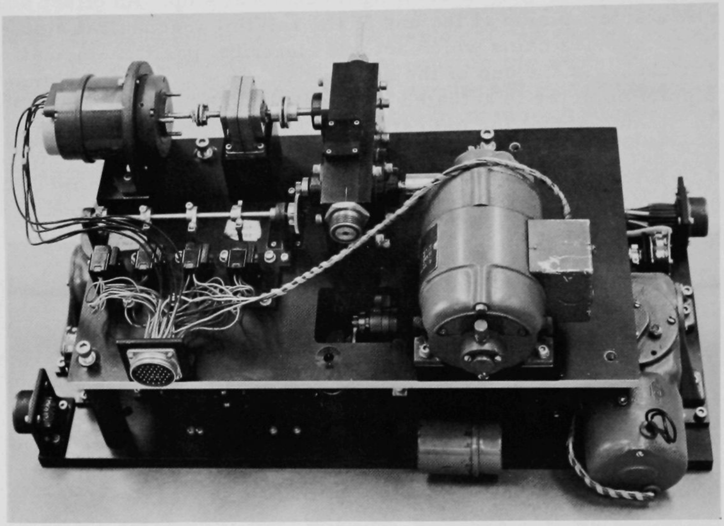


144-290

Fig. 52. Shim-Safety Rod Drive Units

The mechanism for driving the regulating rod employs different components arranged in a different pattern on a mounting plate supported above the one shown in Fig. 52. Five short columns, visible in Fig. 52, provide the support for the drive mechanism for the regulating rod, as may be observed in Fig. 53. One may also observe in Fig. 53 the arrangement of a reversible motor with a right-angled output shaft from an integrally mounted speed reducer connected to an encased Teleflex

Drive pinion. From the opposite side of the pinion case, extend two short shafts. One of these shafts carries a small pinion for driving an offset shaft which is supplied with cams for actuating position-indicating and limit switches. The other short shaft connects with an in-line speed increaser through a small, precision flexible coupling. The speed increaser is in turn connected to a Selsyn generator by another small, precision flexible coupling. The Selsyn generator supplies the signal for driving the Selsyn motor to indicate the position of the regulating rod.



144-291

Fig. 53. Regulating Rod Drive Unit

The drive mechanisms for the shim-safety rods and for the regulating rod are coupled mechanically to their respective control rods by flexible Teleflex cables. These cables are in essence flexible racks engaging the encased Teleflex pinions which have been mentioned. The Teleflex cables move through the pinion casings where they are held in contact with the drive pinions by idler pinions and guide bushings. Teleflex cable conduits and antirotation overrun tubes attach to the pinion cases so the cables will be constrained to linear motion between the described drive mechanisms and other connected Teleflex units employed to provide a 90° change in direction from horizontal to vertical paths.

In the case of the regulating-rod mechanism, the unit for providing the change in direction of motion is another encased Teleflex pinion operating as an idler mounted over the central control rod. The mounting of this encased idler pinion is located so that the vertically moving cable is precisely aligned with the stem of the regulating rod. These two items are joined by a Teleflex quick-connect device and are enclosed by sealed Teleflex cable conduit and a control rod shielding guide plug. The entire drive mechanism, over-run tube, conduit sections, pinion cases, and control rod shielding guide plug installed in the top of the reactor are rendered gastight by mechanical shaft seals and O-ring gaskets. This is also true for the shim-safety rod mechanisms.

The unit for changing the direction of motion of the cables which actuate the shim-safety rods embody encased Teleflex pinions which are spring loaded. These springs are wound up by the engagement of their associated pinions with the Teleflex cables in the process of withdrawing the shim-safety rods from the reactor core. The springs, pinions, cables, and attached control rods are held in the above state by the drive motors with their speed reducers and associated magnetic clutches. Upon de-energization of the clutches, the springs unwind to overcome the moments of inertia of the clutches and the various other rotating parts, and also to overcome friction and inertia associated with the systems. The springs were not intended to result in a downward acceleration of the safety rods appreciably different from that of fall in water under the action of gravity. The anticipated time of rod drop from the full-out position should thus be in the range from about 0.4 to 0.5 sec. Increase of the rod drop time beyond about 0.6 sec would indicate improper performance.

Details of the arrangement of the drive-mechanism assemblies and their various components may be observed by reference to Fig. 54 and Fig. 55, along with the indicated drawings and corresponding bills of materials of the "Janus" drawing file.

J. External Shielding

The "Janus" reactor is completely encased by a system of "External Shielding." Certain units of this shielding may be disassembled to give access to those components of the reactor system which may need to be serviced or replaced. This external removable shielding situated around the reactor may be considered under the five general categories indicated below:

1. Low-dosage Cell Shielding,
2. High-dosage Cell Shielding,
3. Pipe Slot Shielding,
4. Rabbit and Source Tube Shielding, and
5. Top Floor Shielding.

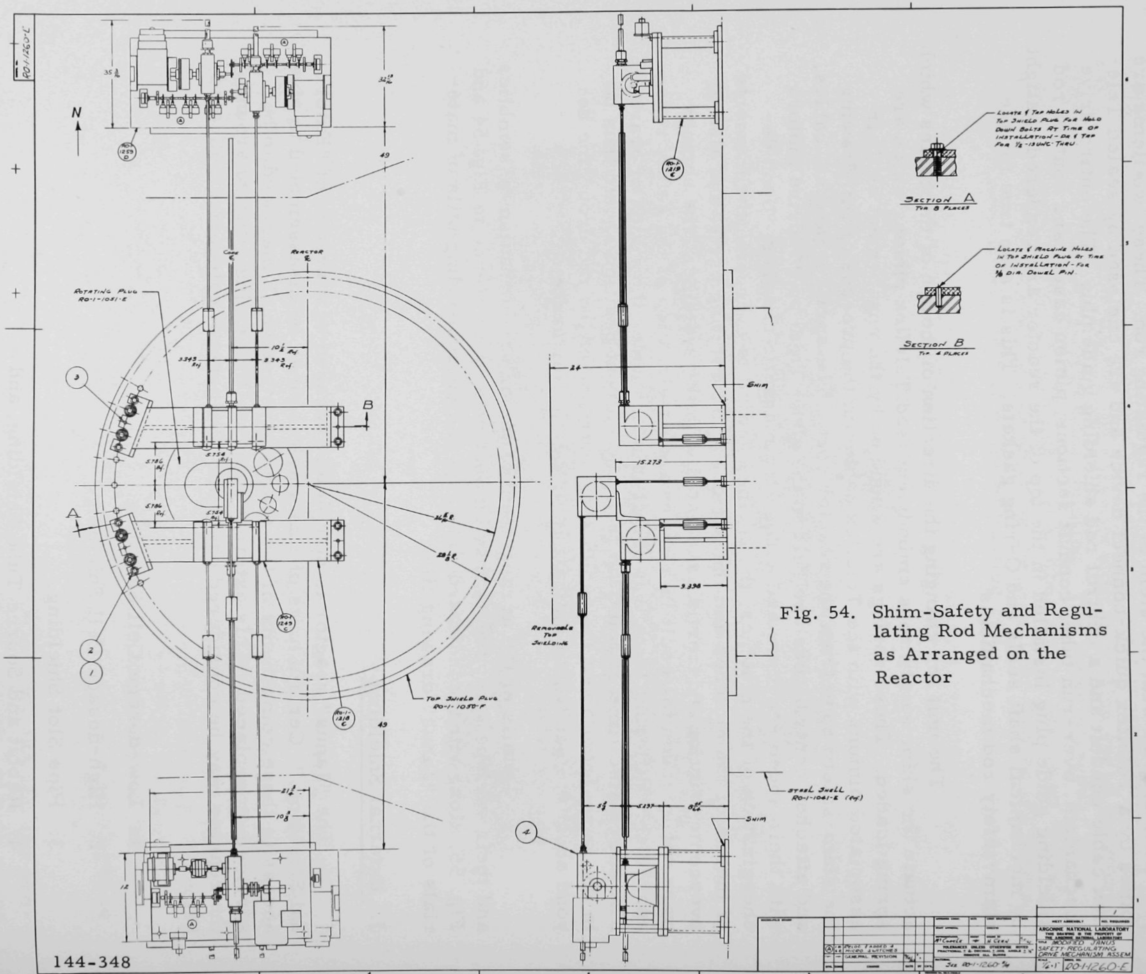
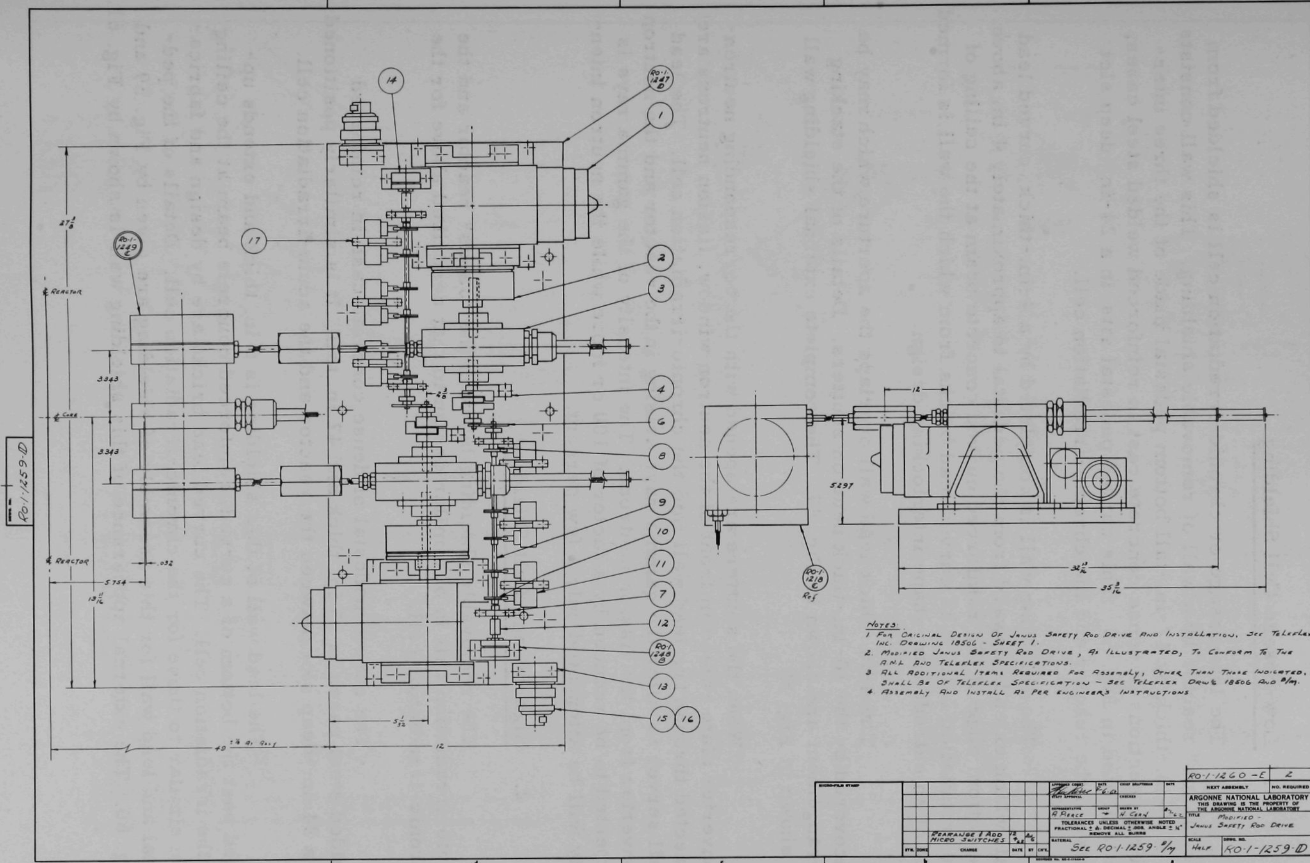


Fig. 54. Shim-Safety and Regulating Rod Mechanisms as Arranged on the Reactor

144-348



144-349 Fig. 55. Assembly Drawing of Shim-Safety Rod Drive Unit

1. Low-dosage Cell Shielding

The low-dosage or chronic-irradiation cell is shielded from the "Janus" reactor by a wall of removable shielding. This wall consists of a 10-in.-thick by 47-in.-tall bottom pedestal made of the three interlocking sections of dense concrete cast in reinforced welded steel cases, as indicated in Fig. 56. This curved pedestal sits in a 24-in.-deep slot between the reactor and the chronic-irradiation cell.

The shielding wall is completed by a 4-in.-thick, curved lead wall which extends upward from the pedestal to approximately 4 in. above the bottom edge of the reinforced curved concrete beam at the ceiling of the irradiation cell. The curved lead bricks from which the wall is formed are of an extruded-to-shape interlocking design.

The 4-in.-thick lead wall overlaps the aperture which may be uncovered by the 10-in.-thick neutron shutters. Details of the stacking arrangement are shown in Fig. 57. The complete external shielding wall is shown in Fig. 58.

When the shutters are opened with the corresponding neutron-converter plate raised in front of the neutron window, fission neutrons are directed through the lead wall into the chronic-irradiation cell. The lead wall serves to filter the gamma rays arising in the reactor and the neutron converter from the fission neutrons. The intensity of the gamma rays is expected to be reduced by a factor of 100 or more while the neutron intensity will be attenuated only a few percent.

2. High-dosage Cell Shielding

The removable shielding between the "Janus" reactor and the acute-irradiation cell is of similar design to that described above for the chronic-irradiation cell.

The curved pedestal of dense concrete cast in reinforced welded steel cases is 15 in. thick and 47 in. tall. It is similarly positioned in a 24-in.-deep slot between the reactor and the acute-irradiation cell.

The lead wall of this shielding is 6 in. thick and extends upward past the bottom of a curved, reinforced concrete beam at the ceiling of the irradiation cell. The curved lead bricks are by design and fabrication similar to those for the chronic-irradiation cell. Details of the pedestal and lead wall for this assembly of shielding are given by Fig. 59 and Fig. 60. The external appearance of this shielding wall is shown by Fig. 61.

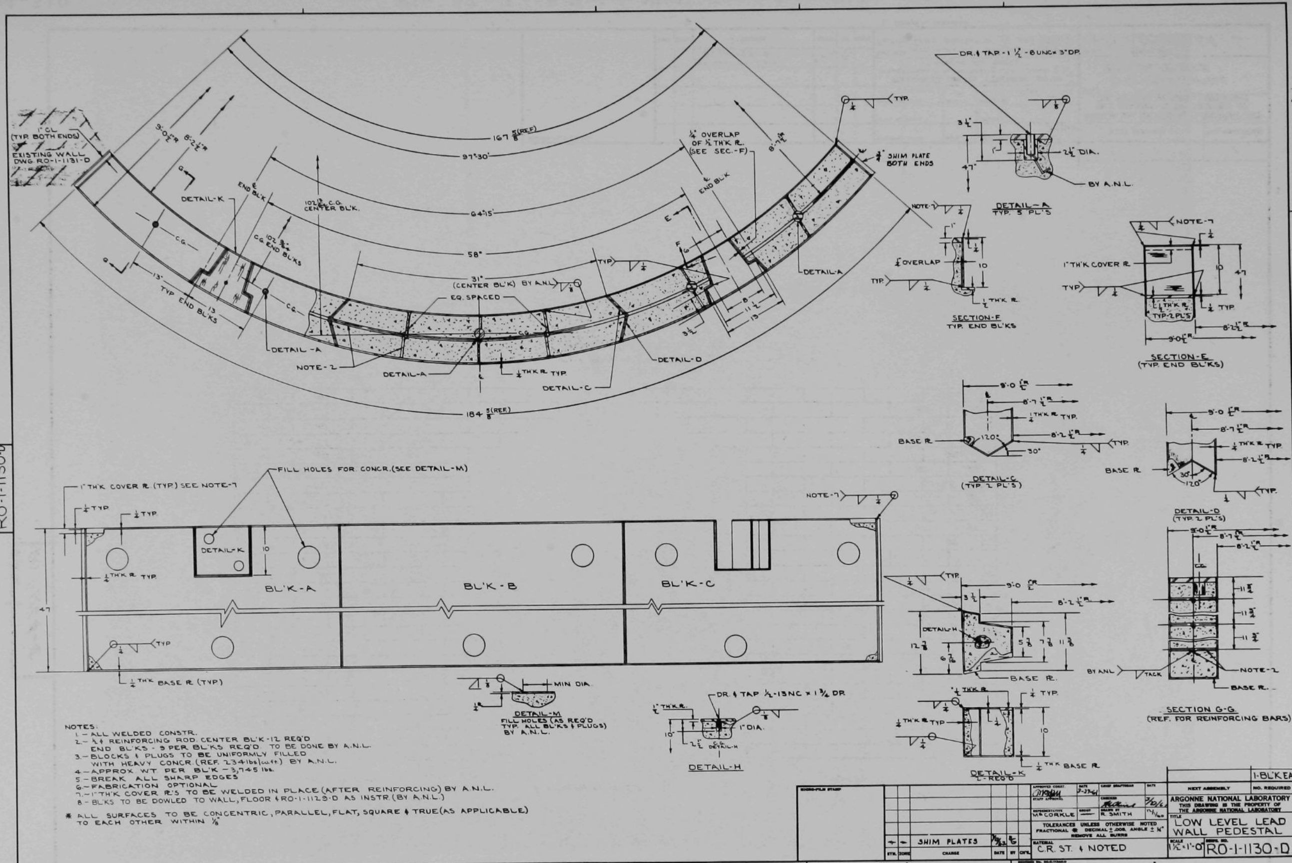
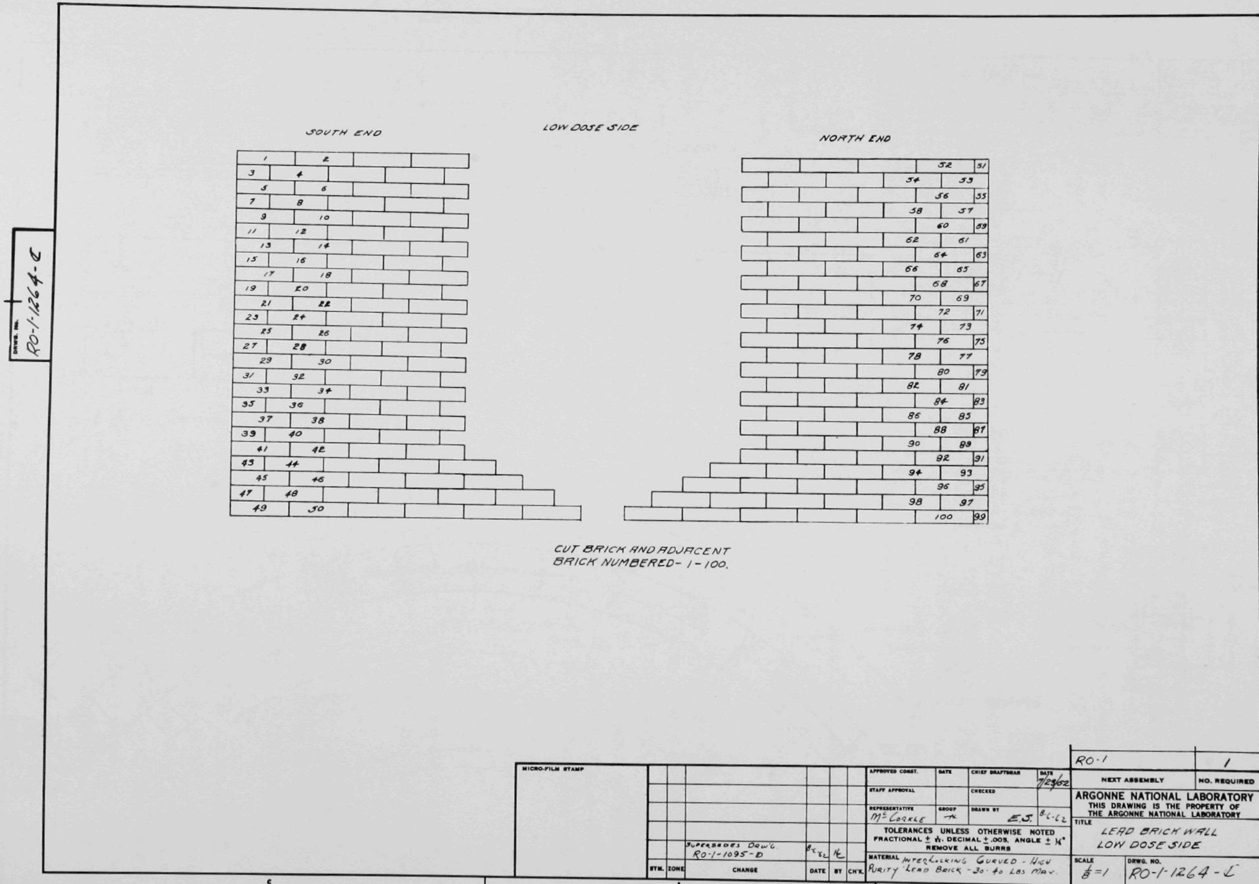


Fig. 56. Low-level Lead Wall Pedestal



144-310

Fig. 57. Lead Brick Wall, Low-dose Side

144-282 Fig. 58. Shielding Wall, Low-level Face

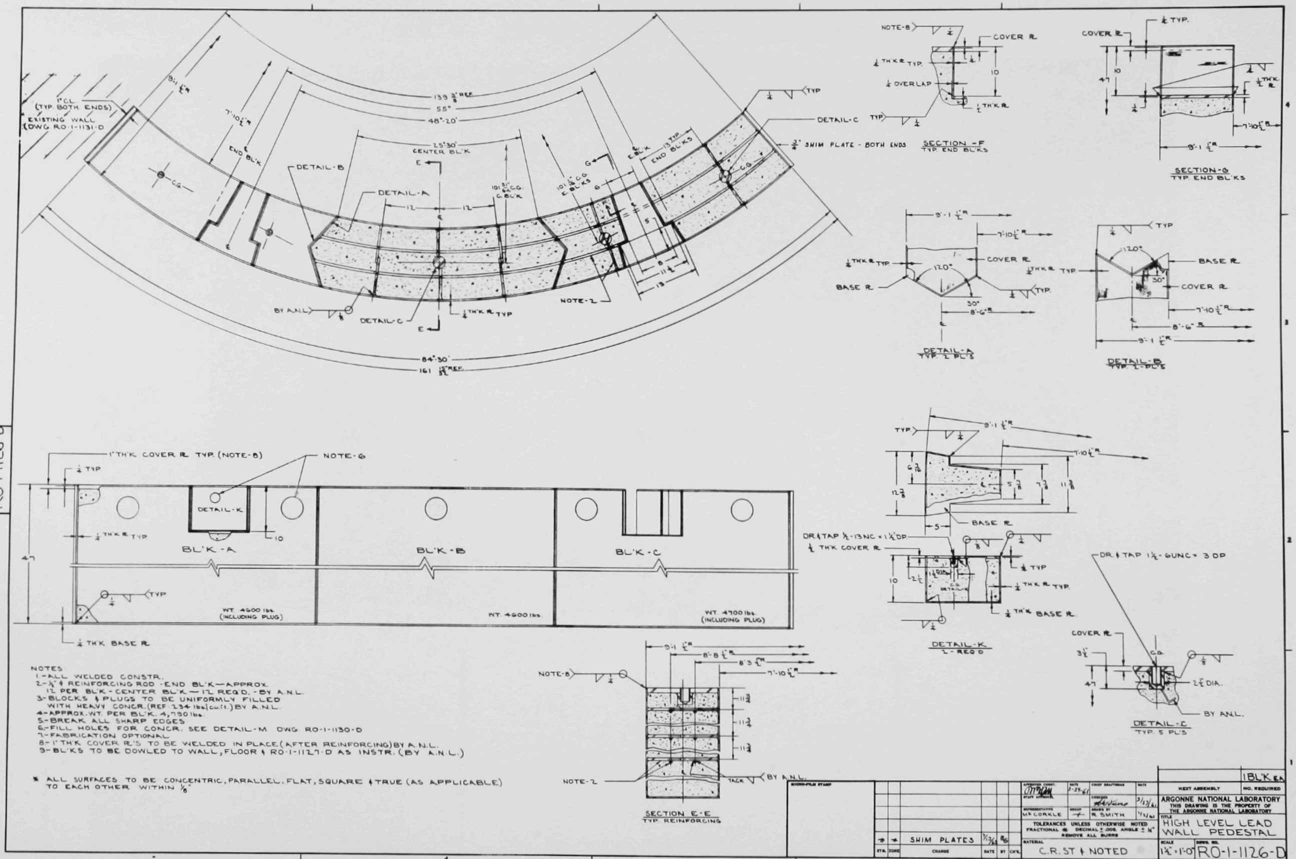
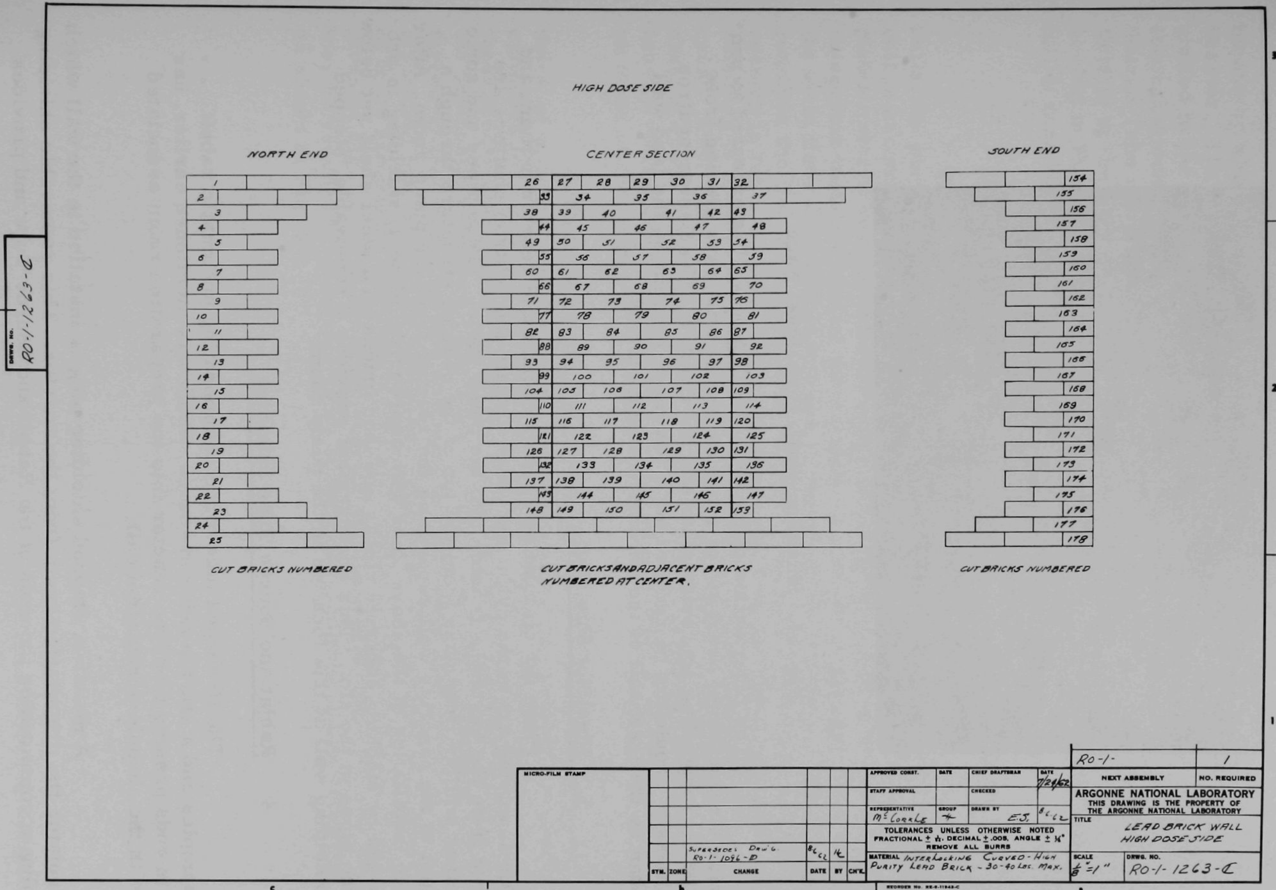
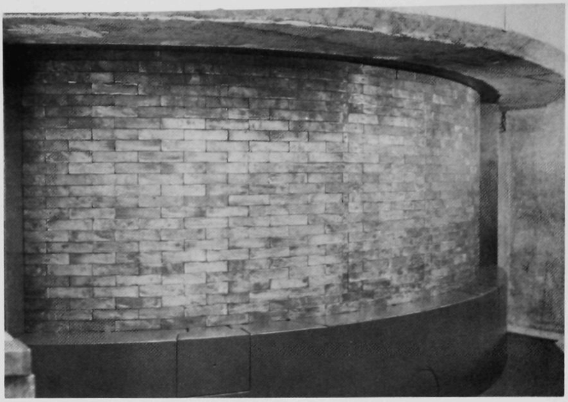


Fig. 59. High-level Lead Wall Pedestal



144-303 Fig. 60. Lead Brick Wall, High-dose Side



144-314

Fig. 61. Shielding Wall, High-level Face

The filter action of the 6-in.-thick lead wall is expected to provide a reduction of about 10^3 or more for the gamma rays coming from the corresponding converter plate and the reactor. The fission-neutron intensity should not be reduced but a few more percent by the lead wall than by the lead wall of the chronic-irradiation cell.

3. Pipe Slot Shielding

Pipes for circulating reactor coolant and reactor helium, and for supplying air to the cylinders which actuate the neutron shutters are run from the top of the reactor into the pump room. These pipes and some other similar lines pass from the top of the reactor structure through a slot in the concrete wall separating the reactor from the pump room. After the installation of the above lines with appropriate offsets, shielding is provided by stacking concrete blocks and lead bricks on a steel shelf set below the pipes in the slot. This arrangement provides a removable, stepped shielding wall at this location in the pump room.

4. Rabbit and Source Tube Shielding

The U-shaped tube for accommodating pneumatic rabbit samples and a startup neutron source, which was mentioned earlier, has its ends passing from the reactor into the preparation room associated with the chronic-irradiation cell.

A massive, stepped shielding plug is installed in the wall which isolates the preparation room from the reactor. This removable shielding plug accommodates the ends of the Rabbit and Source Tube and provides means by which the startup source may be inserted or removed from the reactor. The radiation from the reactor is blocked by a smaller plug installed in the access part of the larger shielding plug and by an S-curve through which the rabbit tube passes in the shielding. The Rabbit and Source Tube may be serviced through removal of the large shielding plug. Details of the construction of this external shielding assembly may be observed in Fig. 39, the indicated detailed drawings, and the corresponding bill of materials.

5. Top Floor Shielding

The isolation of the "Janus" reactor from the irradiation cells, the pump room, and the preparation room for the chronic-irradiation cell is accomplished by closing the neutron shutters with the converter plates lowered and the external shielding of the four presently described categories installed around the reactor. To shield the control room and the main floor area adequately and to complete the isolation of the reactor requires the Top Floor Shielding, which is arranged to be fitted into the opening in the main floor above the top of the reactor. This external shielding is composed of massive, stepped steel-encased blocks of concrete. When these removable shielding blocks are inserted in the floor opening above the reactor, they are supported by ledges provided in the heavily reinforced building structure and by two heavy I-beams resting on other of the ledges.

Certain of these shielding blocks are provided with stepped holes of appropriate dimensions to accommodate and support pneumatic cylinders for operating the neutron shutters. Other cut-out regions in these blocks also provide space for installing the air lines for actuating the pneumatic cylinders. The cut-out regions have their shielding reinforced by lead-filled inserts arranged to supplement that provided by the structural material of the pneumatic cylinders. The general arrangement of these removable shielding blocks and details of their construction are given in Fig. 62. The top of the reactor and the mechanisms located there may be reached by removing some of the central blocks of this shielding, as shown in Fig. 63.

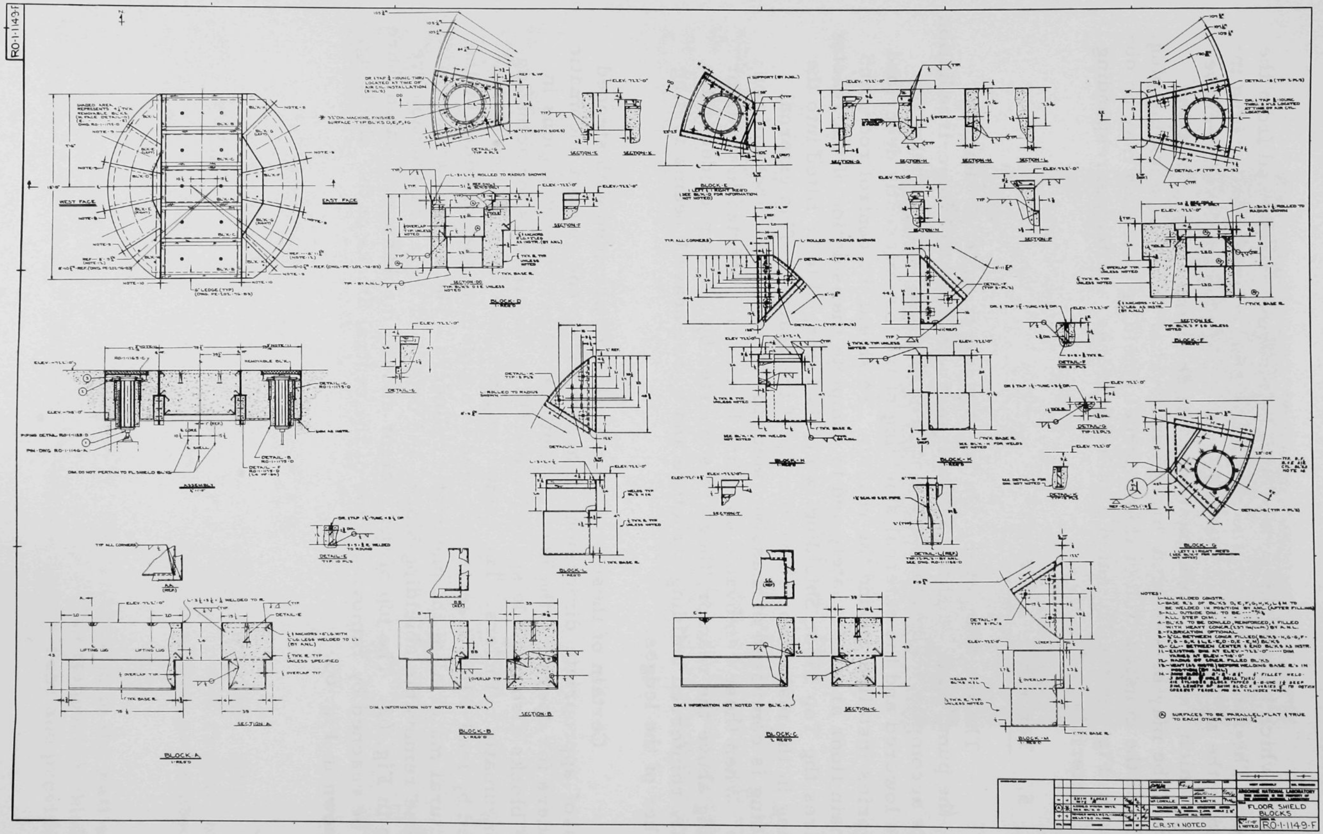
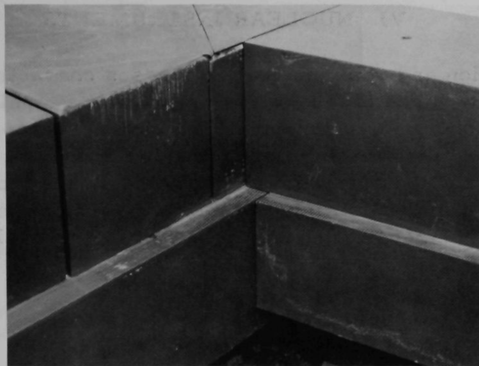


Fig. 62. Floor Shield Blocks



144-337

Fig. 63. Top Floor Shielding Partly Removed

VI. NUCLEAR INSTRUMENTS

The fission and other nuclear processes characteristic of the behavior and performance of the "Janus" reactor are monitored by nuclear instruments which employ appropriate sensing elements and electronic circuitry. In the cases, notably, of the period-meter circuit, the high-flux safety circuits, and the automatic control circuit, the monitoring functions are extended to provide limiting or controlling actions in connection with the operation of the reactor. Descriptions of the several channels are given below.

A. Galvanometer Channel

An electronic galvanometer channel, which is perhaps a misnomer, is used to give a long-scale indication of the neutron density in the "Janus" reactor. The basic circuit could be identical with that of the Safety Trip Amplifier.

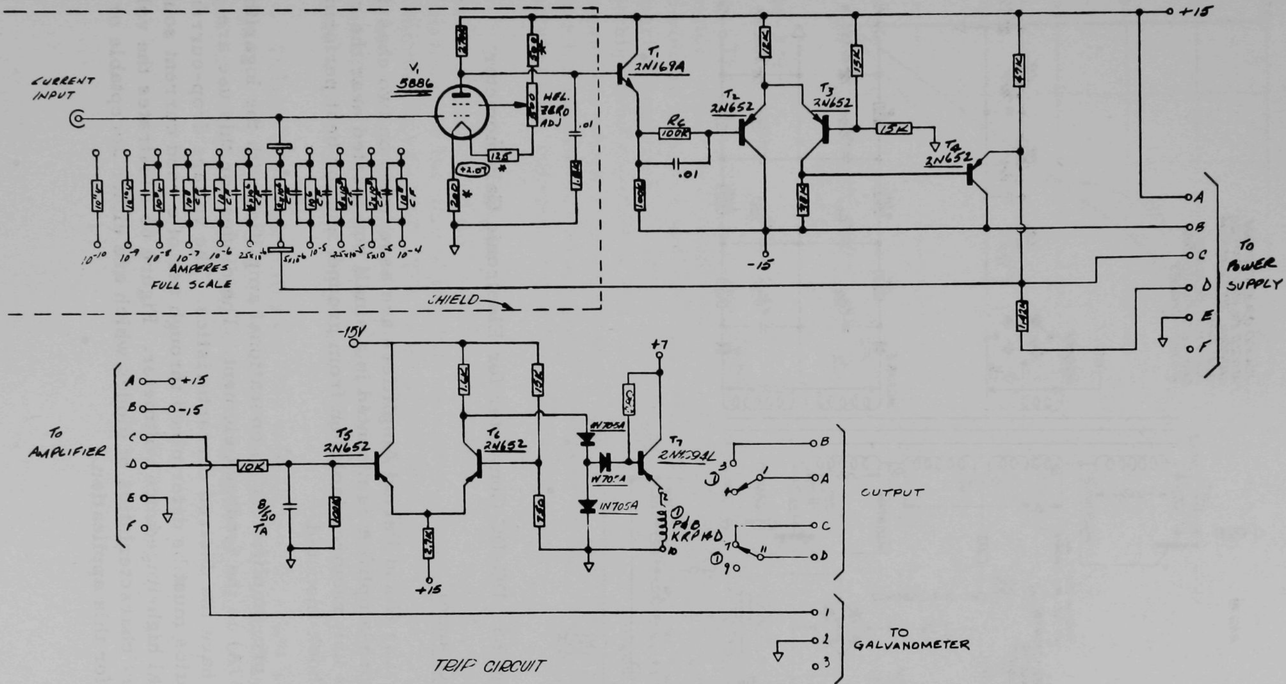
The electronic galvanometer channel uses a range switch and electrometer tube V (5886) which are mounted in a small box located on the main control panel. It has an input current range from 10^{-10} to 10^{-4} amp for full-scale deflection. The range from 10^{-10} to 10^{-6} amp is covered in decade steps. From that range upward, the steps are by the factors 1, 2.5, 5, and 10. This arrangement provides the operator with an expanded scale in the most commonly used power range.

An automatically resetting trip circuit is employed to prevent reactor startup if the neutron flux is lower than an acceptable minimum value. The circuit employs a differential amplifier driving an emitter-follower. The relay is energized except in the tripped condition.

The power supply for the channel has a standby, nickel-cadmium battery, sized to supply the required current to the circuit for 12 to 14 hr under emergency conditions. This battery system will furnish power for the ionization chamber, the electronic circuits, and the galvanometer lamp.

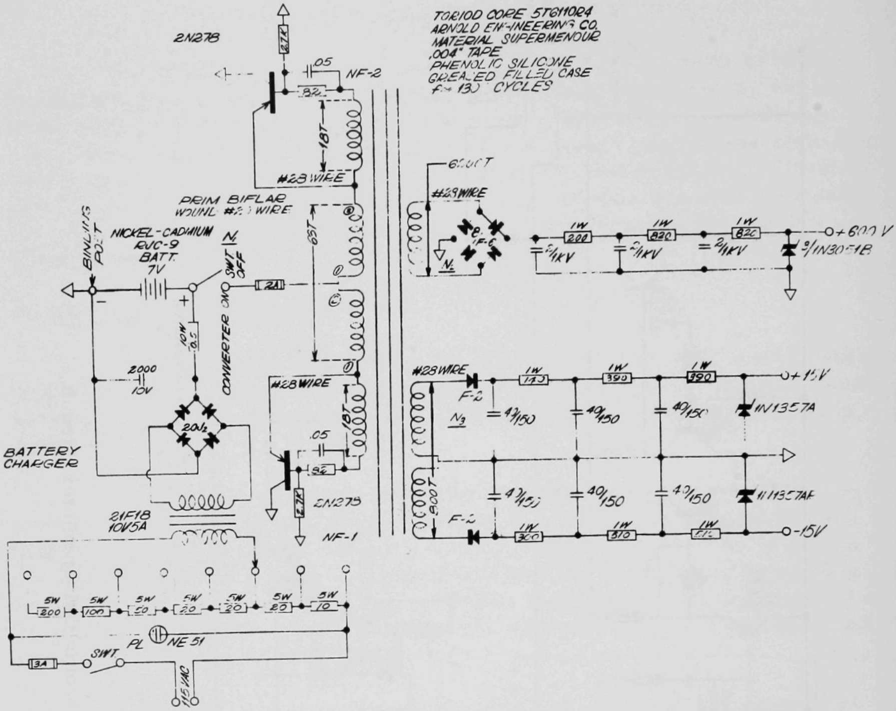
Care of the battery is explained in Appendix C of this manual, with additional information given in the manufacturer's literature.

The circuits of the "Janus" Electronic Galvanometer System and the associated DC-DC converter are given in Fig. 64 and Fig. 65.



144-337

Fig. 64. Electronic Galvanometer Circuit



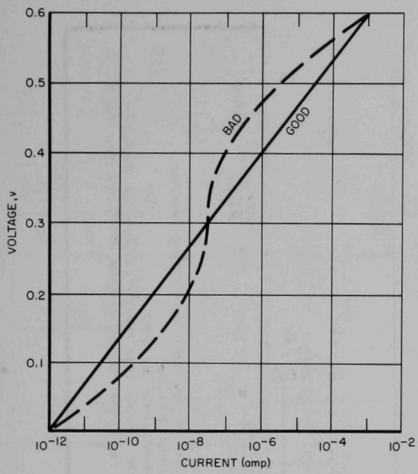
144-338

Fig. 65. DC-DC Converter for Electronic Galvanometer

B. Period Channel

The Log N and Period Amplifiers are assembled on two chassis. The Log N pre-amplifier is mounted in a small box located near the reactor. This unit requires isolation from ground, and for best performance should be shock-mounted.

The pre-amplifier is an operational amplifier with the logarithmic diode (1N137A) as the feedback element. The diodes for this use are selected to have the desired characteristics. The voltage drop-current characteristics must be determined through use of a good current source and a special high-impedance voltmeter. Figure 66 illustrates the voltage drop-current characteristics of diodes which are either acceptable or unacceptable for this application.



144-329

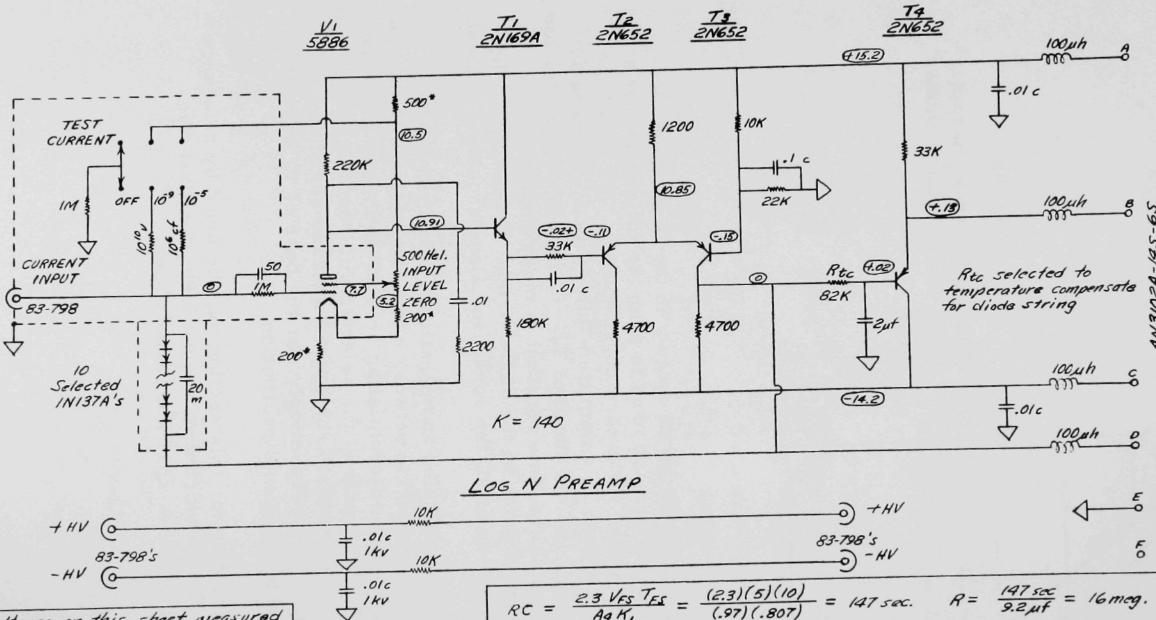
Fig. 66

Voltage-Current Characteristics of Acceptable Diodes

The gain of the pre-amplifier is largely in the first-stage electrometer. The other transistors are used to drop the voltage so that a zero voltage output is provided for a zero current input. The cable and the period amplifier are driven by an emitter-follower T_4. There is a smoothing time constant of 164 ms ahead of T_4. Choice of the resistor for the assembly which supplies the time constant is made mainly for the proper temperature compensation of the diode string. If a change in the smoothing time constant is desired, the condenser alone should be changed.

The Period Amplifier is also an operational amplifier with the resistor of the period differentiating network as its feedback element. The calculations for the size of the differentiating network are shown on Drawing Number EL-A-2647. The value of the selected differentiating condenser must be measured quite accurately. The capacitance and resistance to ground of 0.001 mfd and 3.3 K, respectively, for the base of T_5 provides a phase-shift network which prevents oscillation.

Details of the circuitry for this section may be found by reference to Figs. 67, 68, 69, 70, and 71 which are, respectively, the first five sheets of Drawing Number EL-A-2647 mentioned above.



Voltages on this sheet measured with diode string shorted, INPUT LEVEL ZERO set for zero voltage at T3 collector.

Code

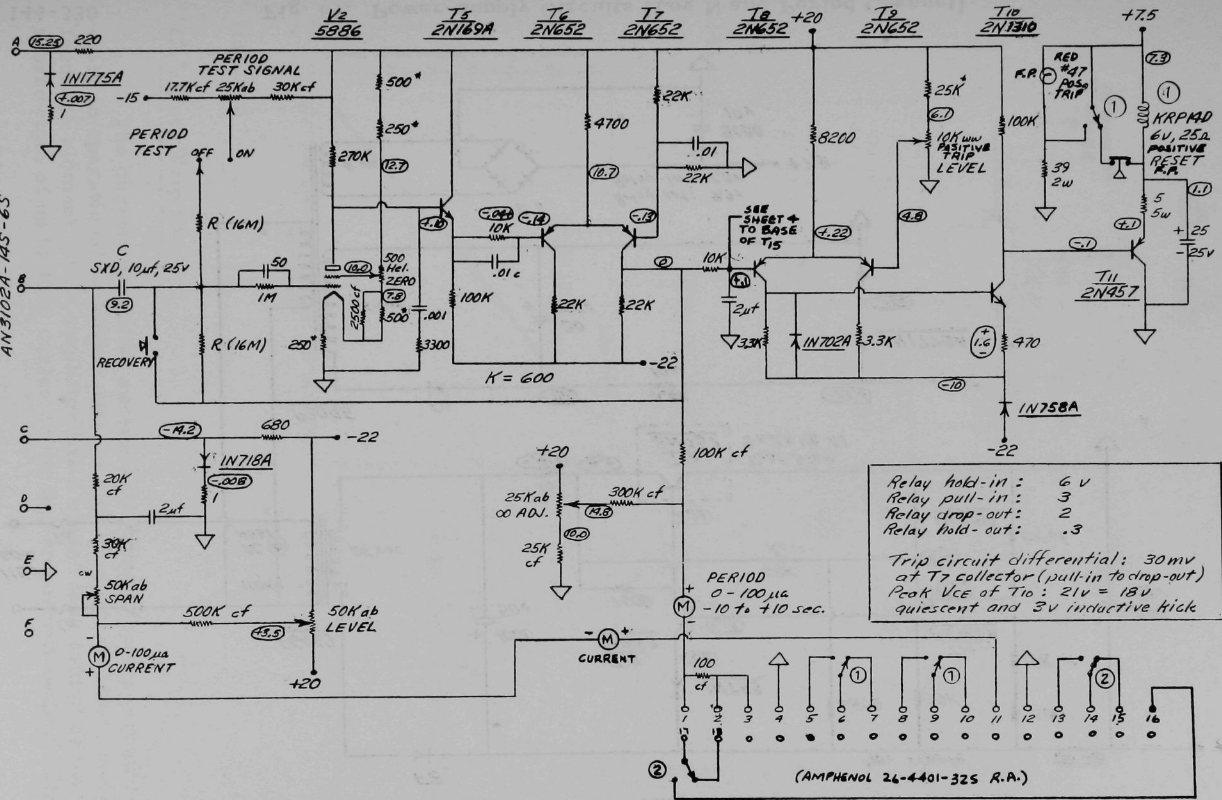
v:	Victoreen resistor
cf:	Carbofilm resistor
c:	Ceramic disc capacitor
m:	Mica capacitor, tall case

$$RC = \frac{2.3\, V_{FS}\, T_{FS}}{A_4 K_1} = \frac{(2.3)(5)(10)}{(.97)(.807)} = 147 \text{ sec.} \qquad R = \frac{147 \text{ sec}}{9.2\, \mu f} = 16 \text{ meg.}$$

R and C:	Shown on Sheet 2
V_{FS} :	Full-scale voltage of period-indicating meter
T_{FS} :	Desired full-scale period
A_4 :	Gain of T_4 - measured as .97
K_1 :	Volts-per-decade diode constant - difference between voltages at T3 collector for 10^{-9} and 10^{-5}, divided by 4.

144-331

Fig. 67. Log N Pre-amplifier (Log N and Period Channel)



144-333

Fig. 68. Differentiator and Trip Circuit (Log N and Period Channel)

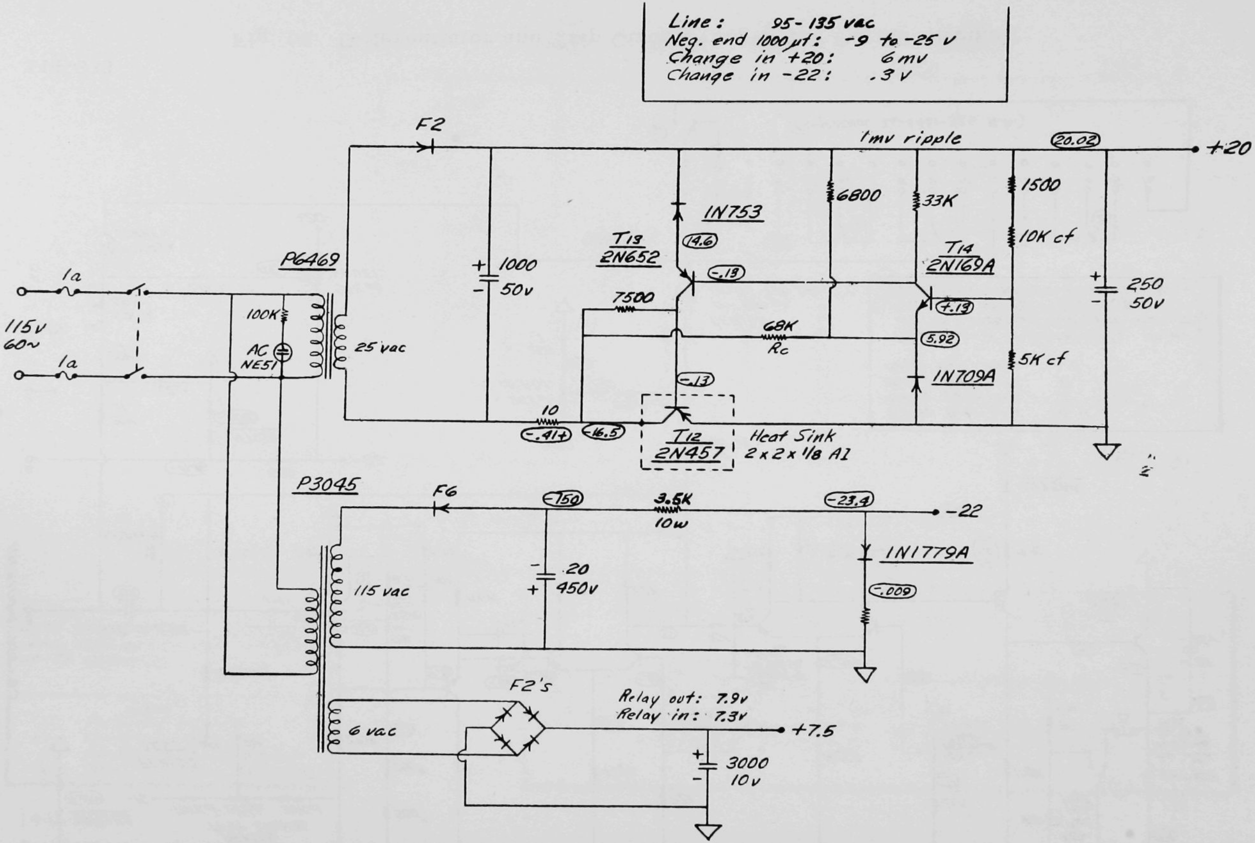
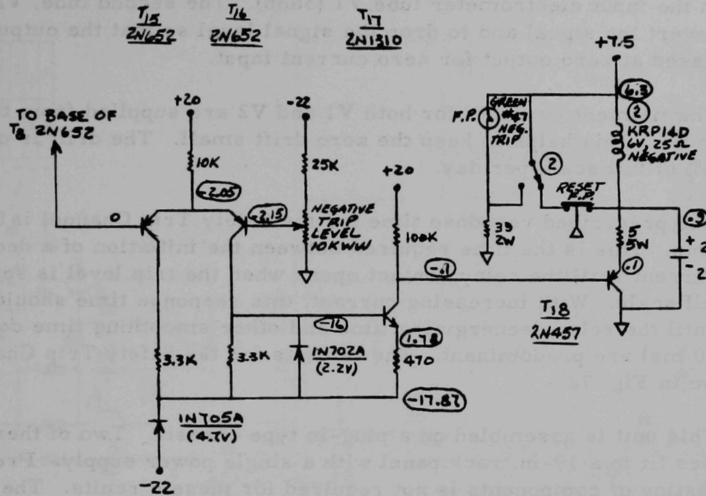


Fig. 69. Power-supply Circuits (Log N and Period Channel)



144-332

Fig. 70. Negative Trip Circuit

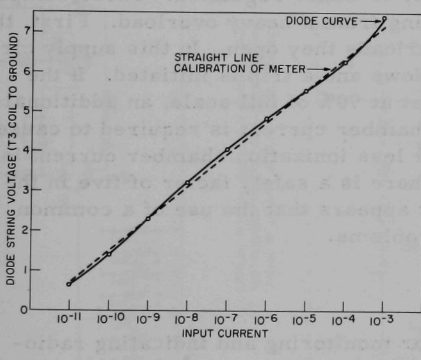


Fig. 71

Diode Characteristic Curve

144-334

C. Safety Trip Channel

The current amplifier section of a "Janus" safety circuit is basically an operational amplifier with its high-ohmage resistor used as the feedback element. This amplifier has a closed loop gain of about 100 and a bandwidth of up to 1000 cycles on the higher current ranges. The gain occurs in the input electrometer tube V1 (5886). The second tube, V2, is used to invert the signal and to drop the signal level so that the output stage can be biased at zero output for zero current input.

The filament currents for both V1 and V2 are supplied from the regulated B^+. This helps to keep the zero drift small. The drift is only about 0.5% of full scale per day.

The prescribed response time for the Safety Trip Channel is 0.1 sec at 10^{-9} amp. This is the time required between the initiation of a decade step of current until the relay contact opens when the trip level is set for 63% of full scale. With increasing current, this response time should decrease until the relay deenergizing time and other smoothing time constants (70 ms) are predominant. The circuits for the Safety Trip Channel are shown in Fig. 72.

This unit is assembled on a plug-in type chassis. Two of these assemblies fit in a 19-in. rack panel with a single power supply. Preselection or testing of components is not required for these circuits. The units have been tested with both the +22- and the -22-v supplies varying, either singularly or in combination. The test of the amplifiers was carried further to determine if a failure in the common power supply would result in a non-fail-safe condition. The supply is Zener regulated. These components have the characteristic of failing from a heavy overload. First, they tend to short; then, with heavier overloads they open. In this supply circuit if either Zener shorts, a fuse blows and a trip is initiated. If the +Zener opens and the trip point is set at 90% of full scale, an additional 11% in magnitude of the ionization chamber current is required to cause a trip. If the -Zener opens, about 22% less ionization chamber current is required at the trip setting. Since there is a safety factor of five in the use vs. rating (2 w to 10 w rated), it appears that the use of a common power supply imposes no serious problems.

D. Radiation Monitors

Gamma Monitors are used for monitoring and indicating radioactivity levels in the irradiation cells and at other selected locations in the "Janus" Irradiation Facility. These monitors are three-decade logarithmic-indicating gamma-sensitive meters. The ionization chamber employed with a monitor has a sensitivity of about 10^{-10} amp/(r/hr)/liter-atmosphere. The chamber size used with a monitor is either one liter or one-tenth liter, depending upon the location where the chamber is used. The nitrogen pressure in a chamber is adjusted to give the sensitivity to the desired accuracy.

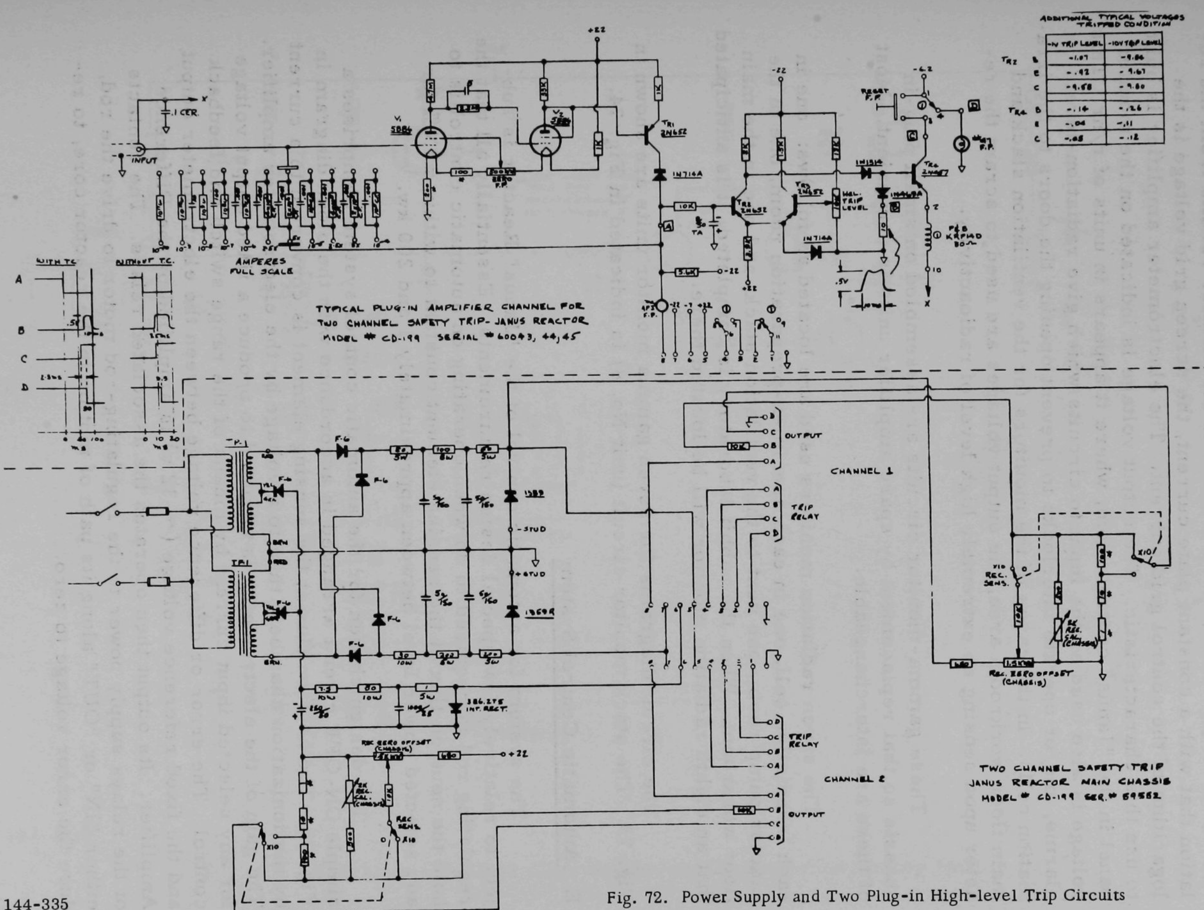


Fig. 72. Power Supply and Two Plug-in High-level Trip Circuits

The logarithmic characteristic of the monitor results from the relation that with a constant plate current, the screen grid voltage is the logarithm of the control grid current. The electrometer amplifier is built to use this characteristic. The output voltage is indicated on the monitor panel in the "Janus" control room, where it appears in units of r/hr. This voltage is also used as the input to circuits which give radiation-level alarms, and/or operate interlocks to prevent opening the doors to the irradiation cells. In the cases of the monitors for the ventilation stack and main floor workroom area, the output voltages are used to scram the reactor upon sensing an extremely high level of radioactivity.

These gamma-monitor circuits are assembled on small plug-in chassis so that replacement by spare amplifier units is convenient. Most of these are interchangeable.

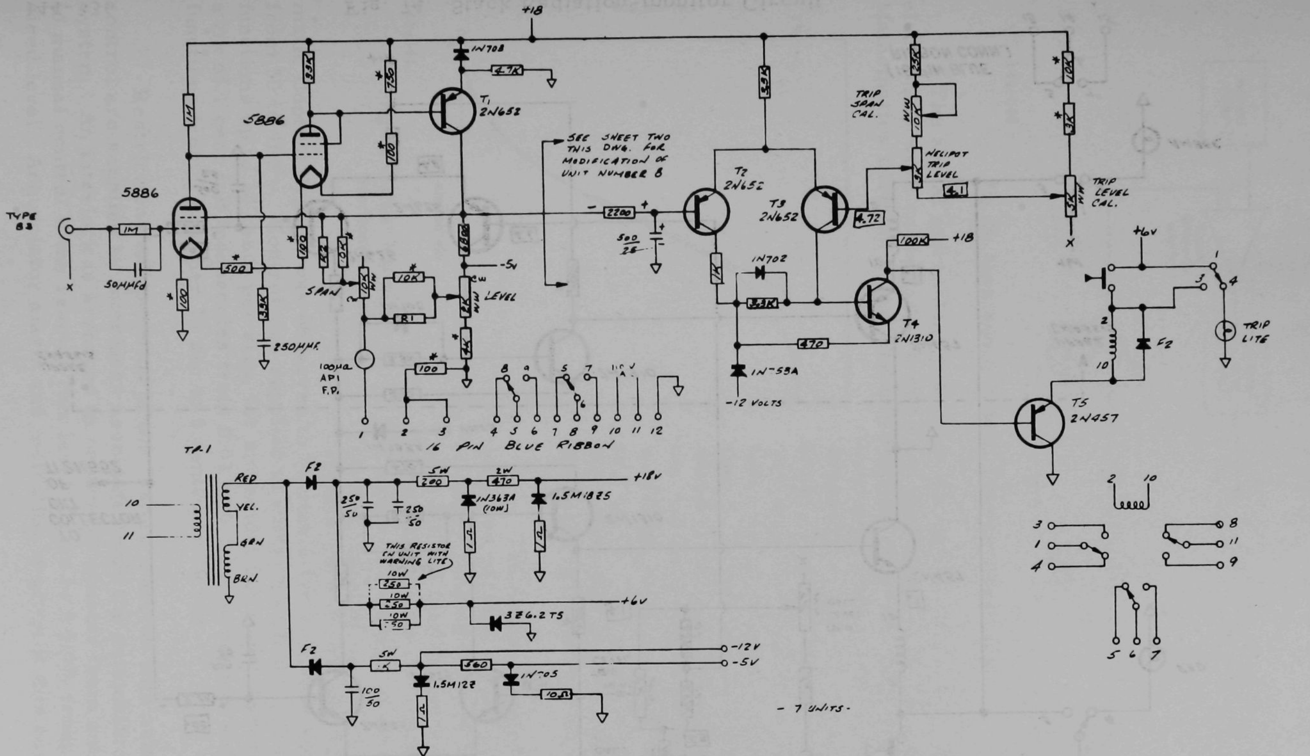
The seven radiation monitors used are located as follows: one in each irradiation cell, one in each specimen-preparation room, one in the reactor pump room, one next to the ventilation stack, and one in the main floor workroom. When the rabbit laboratory is completed, it is anticipated that an eighth radiation monitor will be located there.

The circuit diagrams for seven gamma monitor units are shown in Fig. 73. The stack monitor circuit (unit No. 8) is indicated in Fig. 74.

E. Automatic Control System

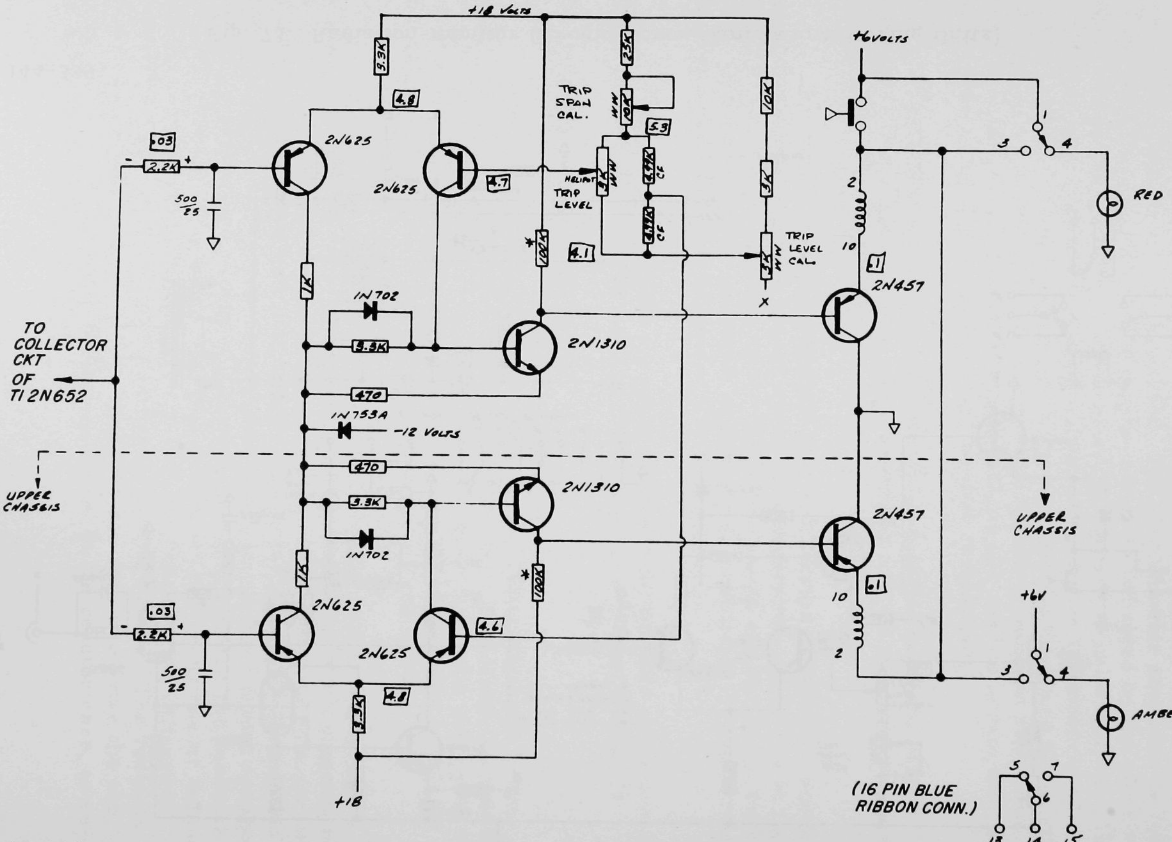
The system for automatic control of the "Janus" Reactor is subject to relatively few special design requirements. Essentially all that the regulating rod is required to do when operating on automatic control is to hold the neutron flux at the sensing element constant to within $\pm 1.0\%$ for any selected power level between approximately 1 and 200 kw.

The design chosen for the automatic control system comprises a simple ON-OFF circuit arranged in accordance with the block diagram in Fig. 75. The neutron flux at the sensing element is converted to a current by the ionization chamber, then to a voltage by the electrometer amplifier. The gain of the electrometer is adjusted to produce a fixed output voltage for any selected input current by means of the range switch and feedback control. The error or difference voltage between the electrometer output and the fixed reference voltage ($\sim$-12 v) is amplified by the Difference Amplifier. Its output then operates the associated relays. The contacts of the relays supply power to the regulating-rod motor to drive the rod, either "IN" or "OUT" along its path of motion in the reactor core, to reduce the error voltage to zero.



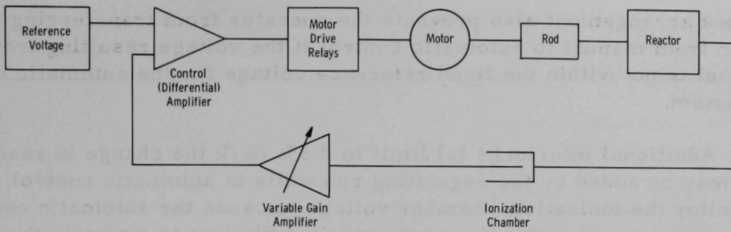
144-339

Fig. 73. Radiation-monitor Circuit (Seven Gamma-monitoring Units)



144-336

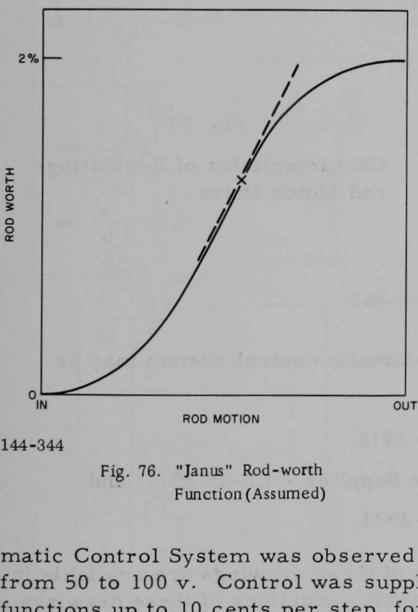
Fig. 74. Stack Radiation-monitor Circuit



144-346

Fig. 75. Block Diagram of "Janus" Automatic Control Circuit

The actual mechanical rod-drive assembly and its associated electronics were connected to a Pace Analog Computer in the Applied Mathematics Division of the Argonne National Laboratory to study the performance characteristics of the Automatic Control System. For this study a neutron lifetime of 100 ms was used, and a value of 0.00686 was taken for the delayed-neutron fraction β. It was also assumed that the shape of the curve of rod position vs. rod worth was described by a modified cosine function, as shown in Fig. 76. The maximum slope of the curve, that of the dashed line, was used in the analog computer study.



144-344

Fig. 76. "Janus" Rod-worth Function (Assumed)

The Analog Computer Analysis was carried out for armature voltages ranging from 50 to 100 v with a fixed lead-lag network incorporated in the Automatic Control Circuit. Responses of the system to step, sinusoidal, and ramp input signals were observed. The Automatic Control System was observed to be stable for all motor voltages from 50 to 100 v. Control was supplied to within ± 1.0% or less for step functions up to 10 cents per step, for sinusoidal functions representing a Δk of 1 cent and frequencies from 0.01 to 0.1 cycle/second, and for ramp functions from 1 cent per 10 sec to 5 cents per 10 sec.

Restrictions on operation of the "Janus" reactor with automatic control are supplied by interlocks associated with the automatic control system. An interlock is arranged to return the reactor from automatic to manual control if the reactor flux level varies by ± 5.0% from the desired level. Annunciator alarm and indication is given if this occurs. The interlock arrangement also prevents the operator from transferring the reactor from manual to automatic control if the voltage resulting from the flux level is not within the fixed reference voltage for the automatic control system.

Additional interlocks (a) limit to 0.5% $\Delta k/k$ the change in reactivity which may be added by the regulating rod while in automatic control, (b) monitor the ionization-chamber voltage to cause the automatic control to revert to manual if this does not remain sufficient to maintain the chamber in a saturated condition, and (c) to drop the regulating rod out of automatic control if the armature voltage of the motor drops to approximately 40 v and/or the field voltage drops to approximately 50 v. The approximate normal operating voltages for the motor are: armature - 80 v; field - 110 v. The characteristics of the regulating-rod motor drive are shown in Fig. 77.

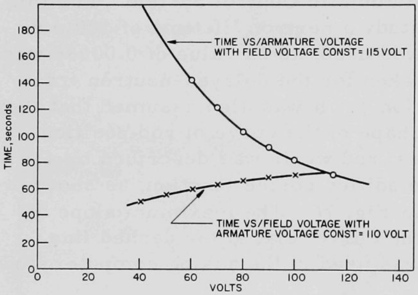


Fig. 77

Characteristics of Regulating-rod Motor Drive

144-345

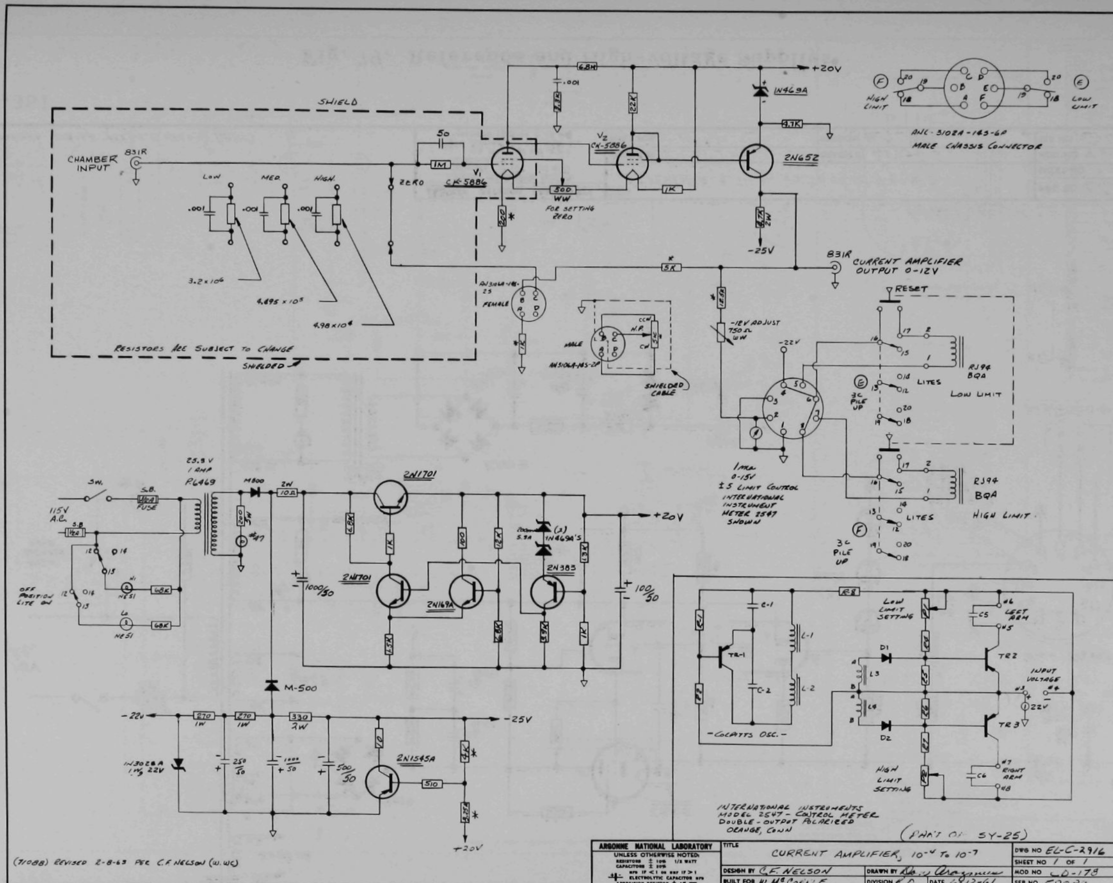
The circuit diagrams for the automatic control system may be found by reference to three drawings:

(a) Current Amplifier - EL-C-2916,

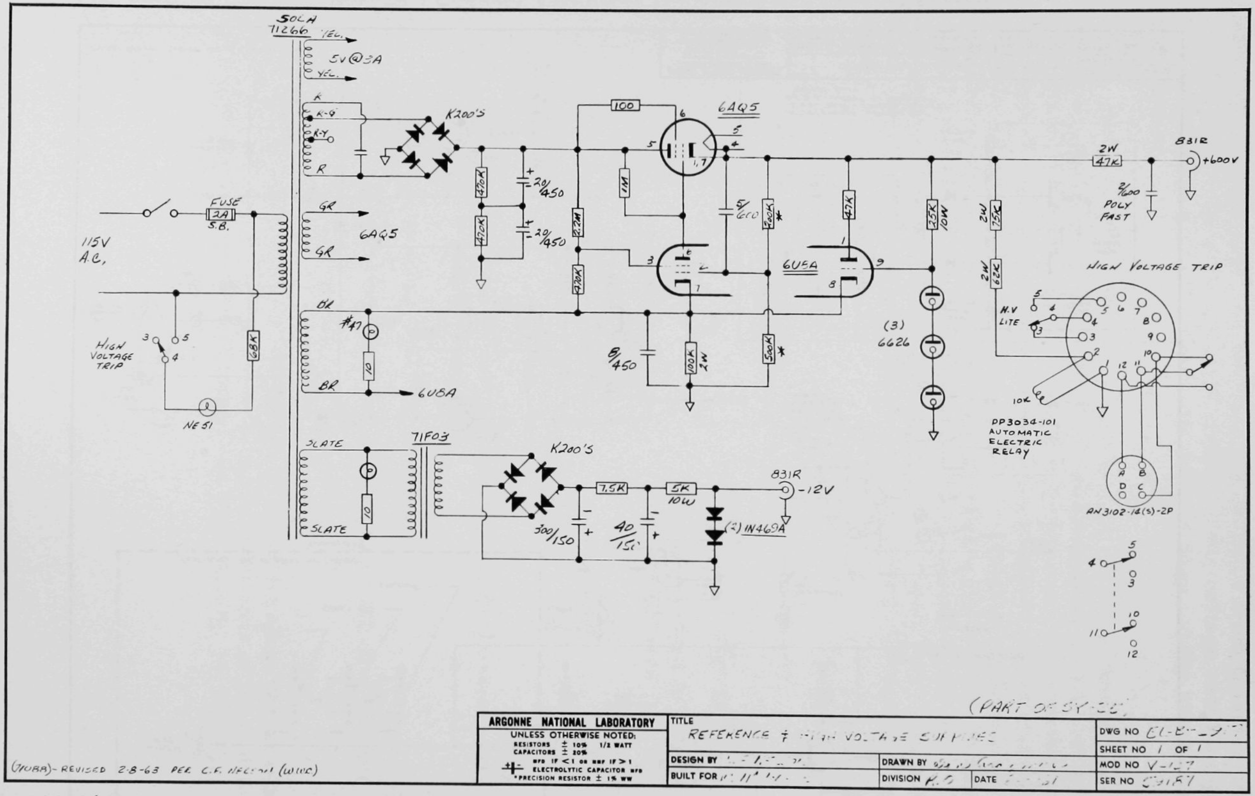
(b) Reference and High Voltage Supplies - EL-B-2917, and

(c) Control Amplifier - EL-D-2921,

which are listed in Appendix A. Prints of these drawings are available in the "Janus" Drawing File, and photographic reductions of these drawings are shown respectively in this manual as Fig. 78, Fig. 79, and Fig. 80.

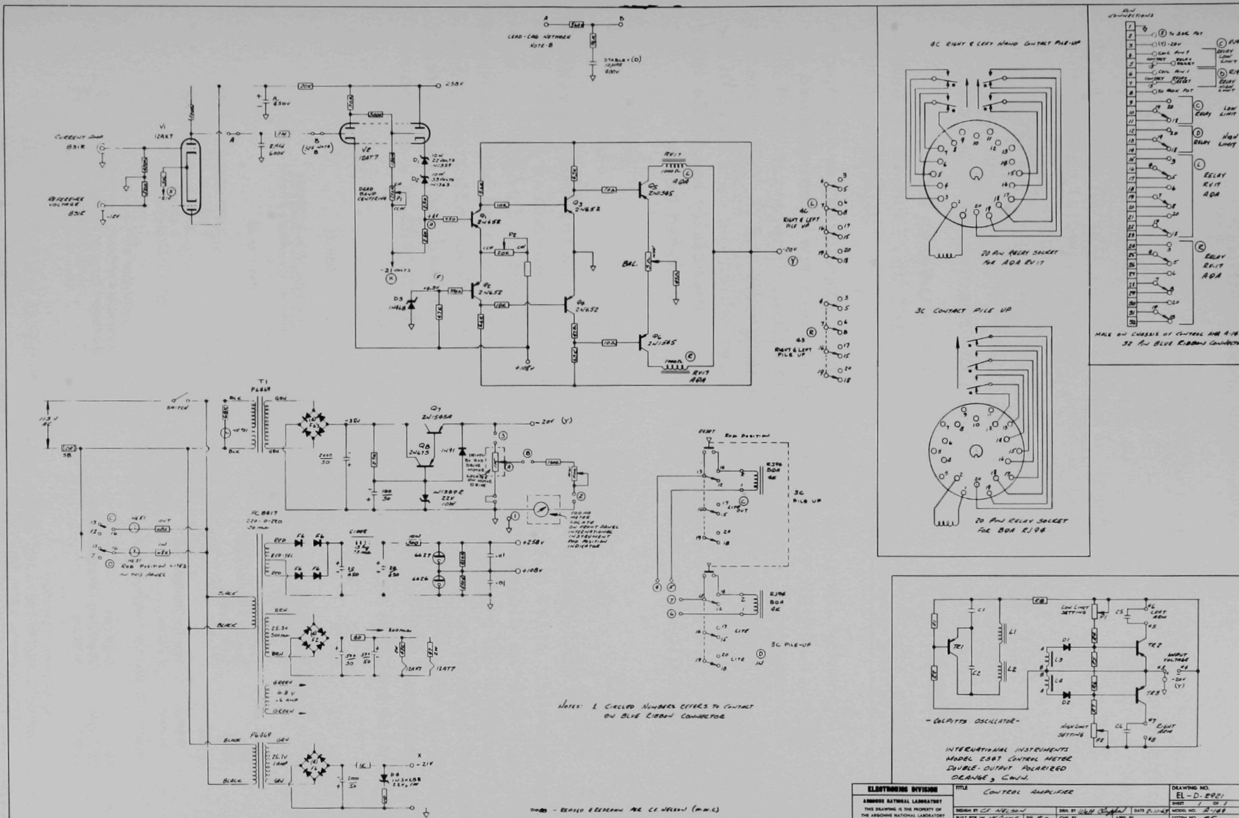


144-362 Fig. 78. Current Amplifier for Automatic Control System



144-361

Fig. 79. Reference and High-voltage Supplies



144-359

Fig. 80. Control Amplifier for Automatic Control System

VII. NON-NUCLEAR INSTRUMENTS

The successful operation of the "Janus" Reactor depends upon being able to monitor processes other than those directly connected with the nuclear fission and chain reaction which is the basic process of the complete system. For example, the release of energy in the fission process, which appears very largely in the form of heat, requires special cooling means for any nuclear reactor which operates at a considerable level of power. Thus, in this section, attention is directed to listing data and other information relative to instrumentation used with the primary and seconary coolants which are circulated respectively through the reactor, and the external system for heat dissipation.

A. Reactor Cooling-water System

Measurements and indications of flows, pressures, and temperatures in various portions of the primary cooling system are accomplished by use of standard commercial instruments listed below. The water level in the reactor tank and the storage tank, the conductivity, and the pH of the water circulated through the reactor are items over which the operators of the reactor should be able to keep watch. Again, commercially available instruments are generally used, and, as above, they are listed below.

1. Flow

The main reactor water flow (circulation through the reactor tank and the shell sides of the heat exchangers) is measured by use of an orifice, of 2.220-in. diameter, mounted between orifice flanges in a section of 3-in. schedule 40 pipe of aluminum. These are located between the outlet side of the heat exchangers and the reactor tank as indicated by Fig. 21. The pressure differential across the orifice is sensed and transmitted to the flow indicator and recorder (see Table XI) by means of a differential pressure cell and flow transducer (see Table X).

Table X

FLOW TRANSDUCER
(Foxboro Flow Transducer)

Foxboro dp cell	Type 13A
Body	Type 316 Stainless Steel
Range	0-100 in. H_2O
Orifice	
Material	Type 316 Stainless Steel
Diameter	3.220 in.
Use with 3-in. schedule 40 pipe.	
Flow	0-200 gpm
Air Supply	20 psig (regulated and filtered)
Output	3-15 psig

Installation and Servicing
covered by Instruction Book No. 1526
The Foxboro Company, Foxboro, Mass.

Table XI

FLOW INDICATOR-RECORDER
(Foxboro IC Flow and Temperature Receiver-Recorder)

Model No. 40

Pens	3 (with common ink supply)
Chart Drive	1 rev/24 hr (electric)
Elements	Bronze Bellows (3-15 psig)
Ranges	0-200 gpm (flow)
	0-60° C (temp)

Installation and Servicing
covered by Instruction Book No. 782
The Foxboro Company, Foxboro, Mass.

2. Pressure

Pressure readings at the inlets and outlets of the heat exchangers enable the operators of the "Janus" reactor to monitor the pressure relation existing between the coolants in the primary and secondary cooling systems at the region of closest proximity to each other. If any defects should develop in the tubes of the heat exchangers or in the seals where the tubes are secured in the tube sheets of the heat exchangers, transfer of water between the two systems would be a function of the pressures existing there.

These pressures for the primary system are measured and indicated by P_3 and P_4 of Fig. 21. The instruments used are described in Tables XII and XIII.

Table XII

PRESSURE TRANSDUCER AND INDICATOR
(Foxboro Pneumatic Indicating Pressure Transmitter)

Model No. 44

Range	0-30 psig
Scale	Eccentric (0-30 uniform)
Element	Spiral (Type 316 Stainless Steel)
Air supply	20 psig
Outlet	3-15 psig

Installation and Servicing
covered by Instruction Book No. 1581
The Foxboro Company, Foxboro, Mass.

Table XIII

REMOTE PRESSURE INDICATOR
(Foxboro Pressure Indicator)

Type	MR Receiver Gage
Range	0-30 psig
Mounting	Flush
Size	3-$\frac{1}{2}$ in. Round

3. Temperature

By combining information on inlet and oulet temperatures at the reactor with the flow rate of water through the reactor, it becomes possible to calculate the power level at which the reactor is operating.

This information then enables calibration of the neutron-sensing instruments which serve for following the power variations and level of the reactor during startup and operation. The temperatures in the primary cooling system at the inlets and outlets of the heat exchangers are measured by T_3 and T_4, as shown in Fig. 21. These values are indicated and recorded by the instrumentation described in Tables XIV and XV.

Table XIV

TEMPERATURE TRANSMITTER
(Foxboro Pneumatic Indicating Transmitter)

Model No. 44

Range	0-60°C
Thermal System	Long Distance
Class and Type	I.B. (Liquid Filled)
Bulb	Code 1442 (316 stainless steel)
Air Supply	20 psig
Output	3-15 psig

Installation and Servicing
covered by Instruction Book No. 1589
The Foxboro Company, Foxboro, Mass.

Table XV

TEMPERATURE INDICATOR AND RECORDER
(Foxboro IC Flow and Temperature Receiver-Recorder)

Model No. 40

Pens	3 (with common ink supply)
Chart Drive	1 rev/24 hr (electric)
Elements	Bronze Bellows (3-15 psig)
Ranges	0-200 gpm (flow) 0-60°C (temp)

Installation and Servicing
covered by Instruction Book No. 782
The Foxboro Company, Foxboro, Mass.

4. Water Levels

It is anticipated that in filling the reactor system with deionized water, both the reactor tank and the storage tank will be calibrated to obtain volume vs. level curves for the two tanks. During subsequent operation of the reactor, it will be useful to monitor the levels of water in these vessels. For this purpose, a bubbler gage system was arranged. The pressures required to maintain a certain rate of escape of helium bubbles into the tanks from the bubble tubes, which are inserted to within a small known distance from the bottoms of the tanks, will (when calibrated) indicate the water levels in the respective tanks.

These pressures may be sensed and transmitted to the reactor control room or other remote location by use of differential pressure cells and transducers or by other suitable means. The devices selected for use with the "Janus" reactor are described in Tables XVI and XVII.

Table XVI

LEVEL TRANSMITTER
(Minneapolis-Honeywell Regulator Co.)

Model No. 292 N1-H4

Range	0-100 in. H_2O
Accuracy	1%
Body	Type 316 stainless steel

Installation and Servicing
covered by booklet for
Model No. 292 N1-H4-11-111-B
Minneapolis-Honeywell Regulator Co.
Minneapolis, Minn.

Table XVII

LEVEL INDICATOR
(Minneapolis-Honewell Regulator Co.)

Model No. 709X6-L

Range	0-100 in. H_2O

Equipped with Mercoid Switches for Level Limit Interlocks

See Minneapolis-Honeywell Catalogue for
description and instructions.

5. pH of Reactor Water

Corrosion of the aluminum in the reactor and its associated components which are exposed to the water moderator-coolant is quite dependent upon the quality of the water. The pH of the water should be held between about 6.5 and 7.0 to keep corrosion small and fine grained. The cleanup system for the "Janus" reactor water is arranged to enable pH measurements to be made on the water coming from the reactor tank or on the water being returned to the reactor from the cleanup system, as may be desired. A schematic diagram showing this arrangement is given in Fig. 22. The pH indicator employed is described in Table XVIII.

Table XVIII

pH INDICATOR
(Beckman Instrument Co.)

Amplifier	Beckman Model W
Range	pH for 2 to 12
Electrodes	Bristol Flow Type #96565
(Described in Bristol Bulletin Q1304)	
Well	Type 316 stainless steel

Installation and Servicing covered in
Beckman Catalogue No. 80343

6. Conductivity of Reactor Water

Another indication of the quality of the reactor water is given by its electrical conductivity. If corrosion of the reactor system is small and the cleanup system is functioning properly, the conductivity of the reactor water should be maintained easily from one to one-half micromho or less. By reading the conductivity of the water entering the cleanup system from the reactor tank and leaving the cleanup system, a check on the performance of the cleanup resin column can also be made. It may be seen from Fig. 22 that provisions have been made for such use of the conductivity meter. The conductivity indicator is described in Table XIX.

Table XIX

CONDUCTIVITY INDICATOR
(Nielsen and Fryer, Inc.)

Industrial Instruments Model No. R13-S30-P47K

Automatic Temperature Compensation	
Response Time	15 sec for full scale
Range	0-10 micromho
Uses Conductivity Cell (Nielsen and Fryer, Inc.) Model No. CEL-1(SS)002	
Mounted in Gate Valve with Teflon-gasketed Removable Cell Element	
Automatic Temperature Compensation between 20 and 90°C	
Range	0-10 micromho

B. Water System for Cooling Tower

The secondary cooling system transfers the reactor heat from the primary cooling system to a cooling tower by use of water circulated through a system of heat exchangers and pumps. This system is also supplied with instrumentation for monitoring the flow rates, pressures, and temperatures for the tube sides of the heat exchangers. Descriptions, and instructions for installation and servicing may be found by reference to corresponding items of the above Reactor Cooling Water System. See respectively:

1. Flow
2. Pressure
3. Temperature.

VIII. MISCELLANEOUS INSTRUMENTS

The "Janus" Irradiation Facility is supplied with a number of instruments which are not directly associated with the operation of the reactor, its irradiation cells and workrooms, or with its cooling systems. Brief descriptions of these are given in this section.

A. Regulating Rod-position Indicators

1. Digital Indication

The rod "cable" drives a pulley whose shaft comes outside the sealed mechanism. This shaft makes roughly 7 revolutions for the approximately 22-in. travel of the rod and drives a Metron (10A30R-S) speed increaser. This, in turn, drives a Beckman Type XV Selsyn transmitter (115-v, 60 cps). The receiver is geared 1 to 1 to a Veeder-Root Model 1128 four-place counter for which 1 shaft revolution is equal to 10 digits. If consideration is given to the backlash in the Metron Speed Reducer and the accuracy of the Selsyns, a position accuracy of about 0.01 in. is achieved.

2. Analog Indication

A meter relay which limits rod travel while in automatic control also provides analog indication of the regulating rod position. The meter is operated in the same manner as the safety rod analog indicators described below.

B. Shim-Safety Rod-position Indicator

1. Analog Indication

A single-turn potentiometer of ±0.5% absolute linearity is driven by a geared down shaft which is used to actuate the limit switches. The position-indicating meter is then connected between the moving arm of the potentiometer and ground. The overall accuracy is about ±5.0%.

C. Wind Instruments

A Texas Electronics Company Mark III Weathermaster unit was purchased. A Kollsman 32V Type No. 403-6056 Selsyn was installed in place of the 6-v Selsyn supplied. The higher voltage gave more torque, so that an insulated disk could be added to the shaft. The disk was made from a printed circuit board and had the copper left on one side, whereas on the other 3 quadrants of copper were removed. The two copper sides were electrically connected together. Two wipers were mounted so that one was on each side of the disk. These were tied into the alarm system. The disk will be installed on the Selsyn shaft when the alarm wind direction has been decided.

D. TV Systems

1. Low-level Irradiation Cell

An RCA TK201 closed-loop TV system was purchased. The RCA pan and tilt mechanism was checked to see if it would operate upside down; it does. The option for remote iris control was used.

A long wire basket was fabricated to be hung around the camera. The basket was hung from limit switches such that if the basket is pushed off center, the down drive of the TV crane is stopped. A Century Lighting Panograph was purchased; in the final installation, the springs were removed and replaced by a cable.

2. High-level Irradiation Cell

An RCA TV Eye system was purchased. This unit has only a 300-line resolution and may not be the best solution. However, at the cost, it seemed like an excellent gamble at the time. A Zenith portable TV set is the monitor.

E. Shutter Timer

A Cramer time unit #521A-6-6S provides a closed contact once a second. This contact, in turn, actuates a Sodeco predetermined counter (TiZ5P1Ecrtz - N52353) with five places. If the shutters worked instantaneously, the timer would program any shutter opening from 1.0 to 99,999 sec with ±1.0-sec accuracy. The Cramer timer has six contacts with a cycle time of 6 sec per revolution, so that each contact is made once every 6 sec. This arrangement provides a longer life for the contacts.

IX. APPENDICES

A. Lists of Available Drawings

1. Building and Services

PE-202-33-B

Neutron Irradiation Facility
(Wing J - Building 202)

Main Floor Plan	PE-202-76-B-3
Main Floor Reinforcing Plan	PE-202-76-B-3A
Roof Framing Plan and Steel Details	PE-202-76-B-4
Roof Plan, Fresh Air Intake, and Miscellaneous Details	PE-202-76-B-5
Miscellaneous Architectural and Structural Details	PE-202-76-B-6
Window and Door Details	PE-202-76-B-7
Door and Lintel Schedules, Miscellaneous Structural Details	PE-202-76-B-8
North and West Elevations	PE-202-76-B-9
South and East Elevations	PE-202-76-B-10
Building Section, Manhole and Sump Details	PE-202-76-B-11
Building Section and Miscellaneous Details	PE-202-76-B-12
Building Sections	PE-202-76-B-13
Reactor Area Door Openings and Tracks	PE-202-76-B-14
Shielding Doors	PE-202-76-B-15
High Dose Access Plug Details	PE-202-76-B-16
Low Dose Access Plug Details	PE-202-76-B-17
Exhaust Stack Plan and Guy Arrangements	PE-202-76-B-18
Exhaust Stack Base and Details	PE-202-76-B-19
Piping Plans - Service Floor	PE-202-76-M-1
Piping Plan - Main Floor and Miscellaneous Details	PE-202-76-M-2
Miscellaneous Piping Details - Service Floor	PE-202-76-M-3
Heating and Cooling Piping Details	PE-202-76-M-4
Supply and Exhaust Ductwork - Service Floor	PE-202-76-M-5
Supply and Exhaust Ductwork - Main Floor	PE-202-76-M-6
Ductwork Sections and Details	PE-202-76-M-7
Single Position Filter Chamber Details	PE-202-76-M-8
Two Position Filter Chamber Details	PE-202-76-M-9
Final and Prefilter Details	PE-202-76-M-10
Underground Exhaust Ductwork and Blower	PE-202-76-M-11
Air Conditioner #1 and Air Flow Control Diagrams	PE-202-76-M-12
Air Conditioner #2 and Miscellaneous Control Diagrams	PE-202-76-M-13
Power Plan - Service Floor and Outside	PE-202-76-E-1
Power Plan - Main Floor	PE-202-76-E-2
Instrument Raceway Plan - Service Floor	PE-202-76-E-3

Lighting Plan - Service Floor	PE-202-76-E-4	
Lighting Plan - Main Floor	PE-202-76-E-5	
Single Line Diagram and Panel Schedule	PE-202-76-E-6	
Schematic Diagrams	PE-202-76-E-7	
Wiring Diagram - Motor Control Center - Service Floor	PE-202-76-E-8	

2. Instrumentation

Electronic Galvanometer Trip Circuit	EL-B-2676	Sheet 1 of 2
Common Emitter DC-DC Converter for Electronic Galvanometer	EL-B-2676	Sheet 2 of 2
Log N and Period Channel (Part of SY-25)	EL-A-2647	Sheet 1 of 7
Log N and Period Channel (Part of SY-25)	EL-A-2647	Sheet 2 of 7
Log N and Period Channel (Part of SY-25)	EL-A-2647	Sheet 3 of 7
Negative Trip Circuit (Part of SY-25)	EL-A-2647	Sheet 4 of 7
Diode Curve	EL-A-2647	Sheet 5 of 7
Power Supply with Two Plug-in Safety Trip Amplifiers and One Spare (Part of SY-25)	EL-C-2680	Sheet 1 of 1
Janus Gamma Monitor	EL-B-2865Q	Sheet 1 of 2
Janus Gamma Monitor (Unit #8)	EL-B-2865Q	Sheet 2 of 2
Janus Nuclear Instrument Range	RO-7-1227-B	
Saturation Characteristics - Neutronics Chamber	RO-7-1228-B	
IC15A Ion Chamber Curve	RO-7-1229-B	

3. Reactor and Irradiation Facilities

Plan View - Top of Reactor (Neutron Radiation Facility Assembly)	RO-1-1000-E-1
East-West Vertical through Janus (Neutron Radiation Facility)	RO-1-1000-E-2
Horizontal Section through Core - Janus (Neutron Radiation Facility)	RO-1-1000-E-3
Reactor Tank - Janus	RO-1-1001-E
Plenum Chamber - Janus	RO-1-1002-E
Plenum Adapter Fuel Assembly	RO-1-1003-A
Straight Brick - Plain	RO-1-1007-B
Source and Adjustable Poison Housing Assembly	RO-1-1010-C
Cylinder for Janus Fuel Rod	RO-1-1011-A
Upper Section of Poison and Source Rod	RO-1-1012-B
Fuel Assembly-Neutron Radiation Facility	RO-1-1013-D
Fuel Tube Subassembly	RO-1-1014-C
Outer Fuel Tube - Janus Element	RO-1-1015-B
Fuel Tubes Inner and Intermediate	RO-1-1016-B
Nose Inlet and Thimble Seat	RO-1-1017-A

Spacer - Upper	RO-1-1018-B
Housing - Upper	RO-1-1019-B
Top Shield Plug - Fuel Rod	RO-1-1020-B
Poison Rod	RO-1-1021-A
Thimble Nose	RO-1-1022-A
Thimble Fuel Tube	RO-1-1023-B
Thimble Extension	RO-1-1024-B
Converter Plates - Janus	RO-1-1025-F
Center Section, 20-in.-thick Shutter	RO-1-1026-D
Cylinder for Janus Source Assembly	RO-1-1027-B
Rod Section for Janus Source Assembly	RO-1-1028-B
End Section, 20-in.-thick Shutter	RO-1-1029-D
Center Section, 10-in.-thick Shutter	RO-1-1030-D
End Section, 10-in.-thick Shutter	RO-1-1031-D
Thimble Tube (Nonfuel Bearing)	RO-1-1032-B
Source Assembly - Janus	RO-1-1033-D
Compression Spring	RO-1-1034-A
Spring Retainer and Plunger	RO-1-1035-B
Lower Spring Retainer	RO-1-1036-A
Antimony Section for Source Assembly	RO-1-1037-C
Extension Rod - Janus Source Assembly	RO-1-1038-C
Beryllium Section and Extension Tube for Janus Source Assembly	RO-1-1039-D
Retention Spring - Janus Source Assembly	RO-1-1040-A
Steel Shell - Janus	RO-1-1041-E
Corner Post - East - Steel Shell	RO-1-1042-B
Corner Post - West - Steel Shell	RO-1-1043-B
Corner Channels - Steel Shell	RO-1-1044-B
Channel Retaining Bar - Steel Shell	RO-1-1045-B
Backup Plate - Steel Shell	RO-1-1046-B
Grid Plate - Janus	RO-1-1047-D
Clevis	RO-1-1048-B
Top Shield Plug - Janus	RO-1-1050-F
Rotating Plug Detail	RO-1-1051-E
Storage Hole	RO-1-1052-C
Shield Plug for Storage Hole	RO-1-1053-C
Spacer and Support for Storage Hole	RO-1-1054-B
Regulating-Safety Rod Assembly	RO-1-1055-E
Thimble Nose - Regulating and Safety Rod	RO-1-1056-A
Guide Rod and Source Assembly	RO-1-1057-C
Regulating-Safety Rod	RO-1-1058-C
Sealing Ring	RO-1-1059-B
Sealing Ring Locking Shoe	RO-1-1060-A
Gasket - Rotating Plug	RO-1-1061-A
Oblong Plug Locking Shoe	RO-1-1062-A
Center Plug Locking Shoe	RO-1-1063-A

Flange Detail - Gas Outlet Side	RO-1-1064-B
Flange Detail - Gas Inlet Side	RO-1-1065-B
Water In/Out Pipe Subassembly	RO-1-1066-C
Shield Plug - Alternate	RO-1-1068-C
Center Plug - Primary	RO-1-1069-C
Janus Reactor Tank Assembly	RO-1-1072-F
Detail - Shielding Plug	RO-1-1073-C
Stud	RO-1-1074-A
Tube Extension and Seal Housing Subassembly	RO-1-1075-D
Instrument Hole Plug	RO-1-1076-B
Instrument Thimble	RO-1-1077-C
Pneumatic Extension Tube	RO-1-1078-C
Seal Compression Ring	RO-1-1079-B
Seal Housing	RO-1-1081-C
Seal Housing Coupling and Plate	RO-1-1082-B
Seal Rings	RO-1-1085-A
Pneumatic Sample Tube	RO-1-1086-C
Liner for Pneumatic Extension Tube Housing	RO-1-1087-C
Shielding for Pneumatic Extension Tube Housing	RO-1-1088-C
Outer Shield Plug Assembly - Rabbit Facility	RO-1-1089-D
Sample Tube Liner and Housing	RO-1-1090-D
Sample Tube Flange Joint	RO-1-1091-B
Source Tube Shield Plug Liner	RO-1-1092-C
Source Tube Shield Plug	RO-1-1093-C
Outer Shield Plug - Rabbit Facility	RO-1-1094-D
Shielding Wall - Low Level Side (Not as Constructed)	RO-1-1095-D
Shielding Wall - High Level Side (Not as Constructed)	RO-1-1096-D
"Janus" Core Buffer	RO-1-1097-E
Flange - Core Buffer Gas Lines	RO-1-1098-C
Horizontal Section through Janus Reactor Core	RO-1-1099-D
Track - Rotating Plug Rollers	RO-1-1100-C
Converter Plates Drive Assembly	RO-1-1101-D
Converter Plates Drive Motor Mounting Bracket	RO-1-1102-B
Converter Plates Drive Stops	RO-1-1103-C
Converter Plates Drive Shafts	RO-1-1104-B
Converter Plate Drum Face Plate	RO-1-1105-B
Converter Plates Drum Shafts	RO-1-1106-C
Wire Rope Drum	RO-1-1107-C
Pillow Block Supports	RO-1-1108-C
Extension Tube	RO-1-1109-B
Small Shielding, Guide and Hold Down Plug	RO-1-1110-C
Large Shielding, Guide and Hold Down Plug	RO-1-1111-C
Roller Assembly - Rotating Plug	RO-1-1117-C
Pillow Blocks Mounting Bracket Base Plates	RO-1-1118-A
Converter Plates Wire Rope Drum Cover	RO-1-1121-B
Cable Drum Pillow Block Supports	RO-1-1122-B
Rabbit Facility Housing	RO-1-1123-D

Converter Plates Connection Detail	RO-1-1125-C
High Level Lead Wall Pedestal	RO-1-1126-D
High Level Shutter Pedestal	RO-1-1127-D
Janus High and Low Level Shutter Assembly	RO-1-1128-D
Low Level Shutter Pedestal	RO-1-1129-D
Low Level Lead Wall Pedestal	RO-1-1130-D
Steel Form - between Building and Steel Shell	RO-1-1131-D
Guide - 20-in.-thick End Section Shutter	RO-1-1132-C
Guide - 10-in.-thick End Section Shutter	RO-1-1133-C
Revised Top Sealing Arrangement	RO-1-1134-A
Fuel Storage Tube Location	RO-1-1135-B
Washer	RO-1-1136-A
Bearing Face Converter Plates	RO-1-1137-C
Center Filler Floor Plugs	RO-1-1138-C
Converter Plate Section	RO-1-1139-B
Shielding Plug	RO-1-1140-C
Cooling Coil and Thermocouple Location for Shell B.	RO-1-1141-D
Brackets - Heat Exchanger	RO-1-1142-C
Janus Thermal Column Sleeve	RO-1-1145-C
Pin and Washer - Shutter Assembly	RO-1-1146-A
Floor Shield Blocks	RO-1-1149-F
Top Shield Plug Cooling Coil	RO-1-1150-D
Locating Form Attenuation Chamber	RO-1-1151-C
Instrumentation Thimbles - Graphite Zone	RO-1-1152-C
Graphite Compartment - Reactor Tank	RO-1-1153-C
Large ("O" Ring Groove) Shielding, Guide and Hold Down Plug	RO-1-1154-C
Detail - Shielding Plug "O" Ring Groove	RO-1-1155-C
3-in. N.P.S. Orifice Flange for Janus Reactor	RO-1-1156-B
Gasket - Attenuation Chamber	RO-1-1157-B
Piping Detail - Heat Exchanger	RO-1-1158-C
Helium Gas Catalyst Chamber	RO-1-1159-D
Shell - Inlet	RO-1-1160-C
Thermocouple Well	RO-1-1161-A
Shell-Outlet	RO-1-1162-D
Drain Detail	RO-1-1164-B
Split Ring for Air Cylinder Flange	RO-1-1165-C
Flange Details Janus Helium Blower	RO-1-1166-B
Helium Blower - Janus	RO-1-1167-D
Mounting Brackets - Blower and Motor	RO-1-1168-C
Fuel Tube (2) Subassembly	RO-1-1169-C
Janus Dummy Rod Assembly	RO-1-1170-C
Janus Reactor Tank Leveling and Support Arrangement	RO-1-1171-D
Janus Thermal Column Graphite Assembly	RO-1-1172-C
Surge Tank Brackets	RO-1-1173-B
Helium Control Panel Plate	RO-1-1174-B
Floor Shield Blocks - Details	RO-1-1175-D

Suction Side Pumps Main Loop	RO-1-1177-B
Helium Control System	RO-1-1178-B
Helium Circulating System	RO-1-1179-D
Screen and Housing	RO-1-1181-C
5-in. Pipe Screen Assembly	RO-1-1182-C
Reactor Water Loop - Schematic	RO-1-1183-D
Pillow Block Anchor Plates	RO-1-1184-C
Air Storage Tank	RO-1-1185-B
Air Cylinder Tank and Details in Pump Room	RO-1-1187-D
Air Cylinder Piping Details	RO-1-1188-D
Cleanup System Piping - Janus	RO-1-1189-C
Modification of Teleflex Wheel Box Subassembly	RO-1-1190-C
Air Cylinder Handling Fixture	RO-1-1191-C
Remote Valve Wiring Schematic	RO-1-1193-B
Bracket - Motor Driven Valve	RO-1-1194-C
Reinforcing Rod Location	RO-1-1195-C
Rotating Plug Centering Spacer	RO-1-1196-B
Support Bracket	RO-1-1197-B
Fuel Storage Drum	RO-1-1198-C
Actuator Mounting Assembly	RO-1-1216-C
Gasometer Control Panel	RO-8-1217-B
Pulley Housing Mounting Bracket	RO-1-1218-C
Motor Drive Mounting Bracket	RO-1-1219-C
Janus Rod Drive Assembly	RO-1-1220-E
Janus 2-in. Pneumatic Tube Assembly (Rabbit)	RO-1-1221-E
Janus Reactor Nuclear Instrumentation	RO-2-1223-D
Janus Control Console	RO-1-1225-C
Janus Primary Cooling Pump Outlet Piping	RO-1-1226-C
High and Low Level Shutter Limit Switch Arrangement	RO-1-1230-D
Vertical Partial Cross Section through Janus Rabbit Assembly	RO-1-1231-D
Emergency Flow Line	RO-1-1232-C
Modification to Reversing Switch - 4-in. Motorized Valve	RO-1-1233-C
Pump Mounting - Secondary System	RO-1-1234-C
Dash Pot Assembly - Safety Rod	RO-1-1235-B
Janus - Safety Rod Drop Timing Switches - Teleflex Drive Assembly	RO-1-1236-B
Teleflex Drive (Isometric Drawing)	RO-6-1237-B
Helium System - Janus	RO-8-1238-C
Location Points for Shutter Pick Up	RO-1-1239-B
Instrument Holes and Thimble Location	RO-1-1240-B
Skimmer Guide and Shielding Plug	RO-1-1241-C
Seal Rings	RO-1-1242-A
Seal Retaining Flange	RO-1-1243-B
Adjustable Skimmer Pipe	RO-1-1244-B
Level Adjusting Flange	RO-1-1245-B

Instrument Air System	RO-1-1246-C
Teleflex Safety Rod Drive Mounting Plate	RO-1-1247-D
Mounting Bracket	RO-1-1248-B
Modified Teleflex Corp. Janus Safety Rods Pulley Box Assembly	RO-1-1249-C
Shaft	RO-1-1250-B
Tie Bar	RO-1-1251-A
Wheel Spacer	RO-1-1252-A
Bushing	RO-1-1253-A
Bushing	RO-1-1254-A
Housing "A" - Equivalent of Teleflex Part #18506-34	RO-1-1255-B
Wheel - 120 Teeth	RO-1-1256-B
Housing Subassembly	RO-1-1257-B
Cooling Coil Location (Steel Shell)	RO-1-1258-D
Modified Janus Safety Rod Drive	RO-1-1259-D
Modified Janus Safety-Regulating Drive Mechanism Assembly	RO-1-1260-E
Exhaust System - Janus	RO-6-1261-C
Special Flanges for Air Cylinder	RO-1-1262-B
Lead Brick Wall - High Dose Side	RO-1-1263-C
Lead Brick Wall - Low Dose Side	RO-1-1264-C
Upper Filter Seat	RO-1-1265-A
Filter Flange	RO-1-1266-B
Lower Filter Seat	RO-1-1267-A
Filter-Intermediate Cover	RO-1-1268-B
Filter-Top Cover	RO-1-1269-B
Filter Body	RO-1-1270-B
Pump and Motor Guard	RO-1-1271-A
H_2O Filter Assembly	RO-1-1272-C
Filter Outlet	RO-1-1273-B
Filter Connection-Rod and Cap	RO-1-1274-B
Skimmer Coupling	RO-1-1275-B
Modified Cam	RO-1-1276-A
Primary Coolant Schematic	RO-1-1277-B
Secondary Coolant Schematic	RO-1-1278-B
Cleanup System Schematic - Janus	RO-1-1279-B
Skimmer System - Janus Reactor	RO-1-1280-B
Helium Systems - Reactor and Graphite	RO-1-1281-B
Simplified Interlock Diagram - Janus	RO-1-1282-D1
Simplified Interlock Diagram - Janus	RO-1-1282-D2
Buffer Shielding Plug Insert	RO-1-1283-A
Adjustable Skimmer - Janus	RO-1-1284-B
pH Resin Column - Janus	RO-1-1285-C
Ion Exchanger Assembly	RO-1-1286-D
Body	RO-1-1287-D
Flange	RO-1-1288-D

Screen Assembly	RO-1-1289-C
Screen #1	RO-1-1290-B
Screen Retainer #1	RO-1-1291-B
Screen #2	RO-1-1292-B
Screen Retainer #2	RO-1-1293-B
Conductivity Cell	RO-1-1294-C
Juggernaut Helium Gasometer	RE-1-31503-E
Stand Tank	RE-1-31504-D
Floating Tank	RE-1-31505-C
Counter Weight	RE-1-31506-B
Guide Tube	RE-1-31507-C
Guide Cable	RE-1-31500-A
Bracket Switch	RE-1-31509-A
Cooling Tower Installation Neutron Irradiation Facility	PE-202-83 Sheet 1 of 2
Cooling Tower Installation Neutron Irradiation Facility	PE-202-83 Sheet 2 of 2
Guide Plan - Building 202	PE-202-33 Sheet 1 of 4
Guide Plan - Building 202	PE-202-33 Sheet 2 of 4
Horizontal Section through Core	No Number-D
Janus Reactor Tank Assembly	No Number-F
Building and Equipment Layout	No Number-F
Control Rod Drive - Janus Reactor	Teleflex-18506 Sheet 1 of 7
Control Rod Drive	Teleflex-18506 Sheet 2 of 7
Control Rod Drive	Teleflex-18506 Sheet 3 of 7
Control Rod Drives - Janus Reactor	Teleflex-18506 Sheet 4 of 7
Control Rod Drive	Teleflex-18506 Sheet 5 of 7
Control Rod Drive	Teleflex-18506 Sheet 6 of 7
Wiring Diagram - Safety and Control Rod Drives - Janus Reactor	Teleflex-18506 Sheet 7 of 7
Bar - Spacer, Conduit Quick Disconnect	Teleflex-XD124A
Shim - Tabulated	Teleflex-15351
Conduit - Stainless Steel Type 304	Teleflex-A6983
Tube - Anti Torque	Teleflex-14856
Spacer - Anti Torque Tube	Teleflex-14857
Core - Cable	Teleflex-A10835
Connector - Anti Torque Tube	Teleflex-14859
Terminal - Cable Disconnect Type	Teleflex-B5509
Name Plate	Teleflex-18170
Rivet - Shoulder Spring Retainer Spring Loaded Box	Teleflex-16026
Screw - Set #10-32	Teleflex-A6996
Cable - Stripped One End, 321 SST	Teleflex-12163
Terminal - Quick Disconnect Type	Teleflex-A10319
Cable - 321 SST	Teleflex-12164

B. List of Bills of Materials

Teleflex Co. Material for Control Rod Drive - Janus (25 sheets)
(Associated with Drawing No. 18506 - 7 sheets)

1. Bills of Materials for Reactor Drawings

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1000-E-1 B/M (BILL OF MATERIAL)

PREPARED BY Goetsch | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1000-E-1	Plan View - top of Reactor	1 *	
	RO-1-1025-F	Converter Plates Janus	See Drawing	See RO-1-1025-F B/M
	RO-1-1041-E	Steel Shell	1	See RO-1-1041-E B/M
	RO-1-1072-F	Reactor Tank Assembly	1	See RO-1-1072-F B/M
	RO-1-1075-D	Tube Extension & Seal Housing Sub-Assembly	1	See RO-1-1075-D B/M
	RO-1-1089-D	Outer Shield Plug Assembly Rabbit Facility	1	See RO-1-1089-D B/M
	RO-1-1095-D	Shielding Wall - Low Level Side	1	See RO-1-1095-D B/M
	RO-1-1096-D	Shielding Wall - High Level Side	1	See RO-1-1096-D B/M
	RO-1-1101-D	Converter Plates Drive Assem.	1	See RO-1-1101-D B/M
	RO-1-1117-C	Roller Assem.-Rotating Plug	3	See RO-1-1117-C B/M
	RO-1-1128-D	High & Low Level Shutter Assem.	1	See RO-1-1128-D B/M
	RO-1-1131-D	Steel Form Between Building and Steel Shell	1	See RO-1-1131-D B/M
	RO-1-1152-C	Instrumentation Thimbles Graphite Zone	3	See RO-1-1152-C B/M
	RO-1-1260-E	Safety Regulating Drive	1	See RO-1-1260-E B/M
	PE-202-76	Building Drawings	1	See PE-202-76

DATE | CHANGE | SYM

DATE | CHANGE | SYM

DATE | CHANGE | SYM

ANL-117 (7-60)

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1000-E-2 B/M (BILL OF MATERIAL)

PREPARED BY Goetsch | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION
	RO-1-1000-E-2	Elevation View E-W	1	*	
	RO-1-1025-F	Converter Plates	See Drawing		See RO-1-1025-F B/M
	RO-1-1041-E	Steel Shell		1	See RO-1-1041-E B/M
	RO-1-1072-F	Janus Reactor Tank Assembly		1	See RO-1-1072-F B/M
	RO-1-1095-D	Shielding Wall-Low Level Side		1	See RO-1-1095-D B/M
	RO-1-1096-D	Shielding Wall-High Level Side		1	See RO-1-1096-D B/M
	RO-1-1101-D	Converter Plates Drive Assem.		1	See RO-1-1101-D B/M
	RO-1-1117-C	Roller Assembly Rotating Plug		3	See RO-1-1117-C B/M
	RO-1-1126-D	High Level Lead Wall Pedestal		1	See RO-1-1126-D B/M
	RO-1-1127-D	High Level Shutter Pedestal		1	See RO-1-1127-D B/M
	RO-1-1128-D	High & Low Level Shutter Assem.		1	See RO-1-1128-D B/M
	RO-1-1129-D	Low Level Shutter Pedestal		1	See RO-1-1129-D B/M
	RO-1-1130-D	High Level Lead Wall Pedestal		1	See RO-1-1130-D B/M
	RO-1-1131-D	Steel Form - Between Building and Steel Shell		1	See RO-1-1131-D B/M
	RO-1-1149-F	Floor Shield Plugs		1	See RO-1-1149-F B/M
	RO-1-1171-D	Reactor Tank Leveling and Support Arrangement		1	See RO-1-1171-D B/M
	RO-1-1220-E	Rod Drive Assembly		1	See RO-1-1220-E B/M
	RO-1-1221-E	2" Pneumatic Tube Assembly (Rabbit)		1	See RO-1-1221-E B/M
	RO-1-1230-D	High & Low Level Shutter Limit		6	See RO-1-1230-D B/M
	PE-202-76	Building Drawing			See PE-202-76

DATE | CHANGE | SYM | DATE | CHANGE | SYM | DATE | CHANGE | SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1000-E-3 B/M (BILL OF MATERIAL)

PREPARED BY Goetsch | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1000-E-3	Plan View Thru Core	1 *	
	RO-1-1025-F	Converter Plates	See Drawing	See RO-1-1025-F B/M
	RO-1-1075-D	Tube Extension & Seal Housing Sub-Assembly	1	See RO-1-1075-D B/M
	RO-1-1089-D	Outer Shield Plug Assembly Rabbit Facility	1	See RO-1-1089-D B/M
	RO-1-1095-D	Shielding Wall--Low Level Side	1	See RO-1-1095-D B/M
	RO-1-1096-D	Shielding Wall--High Level Side	1	See RO-1-1096-D B/M
	RO-1-1126-D	High Level Lead Wall Pedestal	1	See RO-1-1126-D B/M
	RO-1-1128-D	High & Low Level Shutter Assem.	1	See RO-1-1128-D B/M
	RO-1-1130-D	High Level Lead Wall Pedestal	1	See RO-1-1130-D B/M
	RO-1-1131-D	Steel Between Building and Steel Shell	1	See RO-1-1131-D B/M
	RO-1-1152-C	Instrumentation Thimbles Graphite Zone	3	See RO-1-1152-C B/M
	RO-1-1221-E	2" Pneumatic Tube Assembly	1	See RO-1-1221-E B/M

DATE	CHANGE	SYM

ARGONNE NATIONAL LABORATORY RO-1-1013 B/M (BILL OF MATERIAL)

CLASS: MANUFACTURED M; PURCHASED SPECIAL SPEC. P; PURCHASED COMM. RAW R; PURCHASED ARGONNE FINISH A

PREPARED BY Cern | APPROVED BY W.H.Mc | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION	
	RO-1-1013-D	Fuel Assembly Neutron Radiation Facility	1	*		
	RO-1-1003-A	Plenum Adapter - Fuel Ass'y	1		Mag. - Alum. Alloy	
	RO-1-1017-A	Nose Inlet & Thimble Seat	1		1100 Alum.	
	RO-1-1022-A	Thimble Nose	1		2s Alum.	A
	RO-1-1021-A	Poison Strip	1		See Drw'g	
	RO-1-1023-B	Thimble Fuel Tube **	1		See Drw'g	
	RO-1-1032-B	Thimble Tube **	1		2s Alum.	
	RO-1-1010-C	Source & Adjustable Poison Housing Assembly	1	*	See Drw'g	
	RO-1-1011-A	Cylinder for Janus Fuel Rod		1	Beryllium	
	RO-1-1014-C	Fuel Tube Sub-Assembly (3)	1	*	See Drw'g	
	RO-1-1015-B	Outer Fuel Tube Janus Element		1	See Drw'g	
	RO-1-1016-B	Fuel Tube, Inner & Intermediate		1	See Drw'g	
	RO-1-1018-B	Spacer - Upper	1		1100 Alum.	A
	RO-1-1024-B	Thimble Extension	1		2s Alum.	A
	RO-1-1019-B	Housing - Upper	1		2s Alum.	A
	RO-1-1012-B	Upper Section - Poison & Source Rod	1		See Drw'g	
	RO-1-1020-B	Top Shield Plug - Fuel Rod	1		See Drw'g	
A	RO-1-1169-C	Fuel Tube (2) Sub Assembly##	1		See Drw'g	

** Interchange as per engineer's instructions

Interchange with RO-1-1014-C as per instructions

SYM	DATE	CHANGE
A	4-18-61	RO-1-1169-C Added
A	3/19/59	Changed Material Spec.
B	4/20/59	Thimble tube added

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1033 B/M (BILL OF MATERIAL)

PREPARED BY H. Cern | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT						MATERIAL DESCRIPTION
	RO-1-1033-D	Source Assembly - Janus	1	*					
1		1/8 Dia x 1 3/8 Lg Dowel Pin		1					SST
	RO-1-1034-A	Compress Spring		1					SST
	RO-1-1035-B	Spring Retainer & Plunger		1					304 SST
	RO-1-1036-A	Lower Spring Retainer		1					304 SST
	RO-1-1037-C	Antimony Section		1	*				1100 Alum. & See Drw'g
	RO-1-1028-B	Rod Section			1				Antimony
	RO-1-1038-C	Extension Rod		1					5052 or 6063 Alum.
	RO-1-1039-D	Beryllium Section & Extension Tube		1	*				2 S Alum. & See Drw'g
	RO-1-1027-B	Cylinder			1				Beryllium - See Drw'g
	RO-1-1040-A	Retention Spring		1					SST Wire

DATE	CHANGE	SYM

ARGONNE NATIONAL LABORATORY RO-1-1055 B/M (BILL OF MATERIAL)

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

PREPARED BY J. Moudry | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT			MATERIAL DESCRIPTION
	RO-1-1055-E	JANUS, Reg-Safety Rod Assembly	7	*		See Drawing
	RO-1-1056-A	Thimble Nose		1		1100 Alum.
	RO-1-1057-C	Guide Rod & Source Assembly		1		See Drawing
	RO-1-1032-B	Thimble Tube (Non-Fuel Bearing)		1		1100 Alum.
	RO-1-1058-C	Reg.-Safety Rod		1		See Drawing
1		#10-24-NCX 9/16 long-Soc-Hex. Hd. Mach. Scr.			3	
	RO-1-1003-A	Plenum Adaptor		1		
	RO-1-1014-C	Fuel Tube Subassembly		1		
	RO-1-1015-B	Outer Fuel Tube			1	
	RO-1-1016-B	Inner Fuel Tubes			2	
	RO-1-1017-A	Nose Inlet & Thimble Seat			1	
	RO-1-1018-B	Upper Spacer		1		
	RO-1-1019-B	Upper Housing		1		
	RO-1-1020-B	Top Shield Plug		1		

SYM	CHANGE	DATE
A	RO-1-1110-C & RO-1-1111-C OBSOLETE	12-2-60

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1072 B/M (BILL OF MATERIAL)

PREPARED BY H. Cern | APPROVED BY | SHEET 1 OF 2 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1072-R	Janus Reactor Tank Assembly	1	
1		Flexitallic Gasket (type R-150#) 51-1/8 ID x 51 3/4 OD x .175 Th'k	1	SST - Teflon Filler
2		Hex Nut - 3/4 -10	48	SST
3		Washer - 3/4 - Plain	48	SST
4		Flexitallic Gasket (Type R-1) 4 OD x 3-1/2 ID x .125 Th'k	2	SST - Teflon Filler
5		Linear "O" Gasket 7 1/4 ID x 7 1/2 OD x 1/8 W Cat. #1866-41	1	Hypalon
6		Hex. Hd. Scr. 3/8-16 x 2" Lg.	12	Al.-Mag. Alloy
7		Washer - 3/8 Plain	12	Al.-Mag. Alloy
8		Flexitallic Gasket - R3-16 2-29/32 ID x 3-19/32 OD x .125 Th'k	2	SST Teflon Filler
9		Soc. Hd. Scr. - 1/2-13 x 2¼ Lg	16	SST
10		Washer - 1/2 - Plain	16	SST
11		¼ OD x .049 (18 Ga) Tubing	1	6061 Al. Lg. as Req'd
12		Swagelock - Special Heat Exchanger Tee Fitting Jacketing Tube 1" OD x Process Tube 1/4 OD x Branch Tube 1" OD	1	SST
13		1" OD x .065 (16 Ga) Tubing	1	6061 Al. Lg. as Req'd
14		Swagelock - Male Connector Cat. No. 1610-1-12-316	1	SST
15		Swagelock - Male Elbow Cat. No. 1610-2-12-316	1	SST
16		Soc. Hd. Cap Scr. ¼-20 x 3/4 Lg	26	SST
17		Linear "O" Gasket-#11-226 1984 ID x 2262 OD x .139 W	7	Hypalon
18		Soc. Hd. Cap. Scr.-3/8-16 x 1 Lg	6	SST
19		Linear "O" Gasket #11-242 3.984 ID x 4262 OD x 139 W	1	Hypalon
20		Flexitallic Gasket - D-1E 1-11/16 ID x 2-3/8 OD .125 Th'k	2	SST - Teflon Filler
21		Hex. Hd. Scr.-5/8-11 x 2" Lg.	8	SST
22		Washer - 5/8 Plain	8	SST
23		Flexitallic Gasket D-ID 1¼ ID x 1-7/8 OD x .125 Th'k	1	SST - Teflon Filler
24		Flexitallic Gasket CG-1I 3-3/4 ID x 4-3/4 OD (5-3/8 Ring OD)	1	SST - Teflon Filler
25		Hex. Hd. Bolt 5/8-11 UNU x 2" Lg.	8	SST
26		5/8 Plain Washer	8	SST
27		Flexitallic Gasket Type R-150# 53-1/2 ID x 54-1/8 OD x .175 Th'k	1	SST - Teflon Filler
28		Soc. Hd. Scr.-1/2-13UNC x 1" Lg	4	SST

DATE	CHANGE	SYM

CLASS	
MANU-FACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1072 B/M cont. (BILL OF MATERIAL)

PREPARED BY H. Cern | APPROVED BY | SHEET 2 OF 2 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1072-F	Janus Reactor Tank		
		Assembly - Continued		
	RO-1-1001-E	Reactor Tank - Janus	1	See Drawing
	RO-1-1002-E	Plenum Chamber - Janus	1	See Drawing
	RO-1-1050-F	Top Shield Plug - Janus	1	See Drawing
	RO-1-1074-A	Stud	48	SST
	RO-1-1064-B	Flange - Gas Outlet	1	SST
	RO-1-1060-A	Locking Shoe Sealing Ring	6	SST
	RO-1-1059-B	Sealing Ring	1	SST
	RO-1-1051-E	Rotating Plug - Janus	1	See Drawing
	RO-1-1061-A	Gasket - Rotating Plug	1	Hypalon
	RO-1-1047-D	Grid Plate - Janus	1	1100 Alum.
	RO-1-1063-A	Locking Shoe - Center Plug	10	SST
	RO-1-1069-C	Center Plug - Primary	1	See Drawing
	RO-1-1062-A	Locking Shoe - Oblong Plug	6	SST
	RO-1-1073-C	Shielding Plug - Detail	3	See Drawing
	RO-1-1013-D	Fuel Ass'y	19	See Drawing
	RO-1-1066-C	Water in/out Pipe Sub-assembly	2	See Drawing
	RO-1-1075-E	Tube Extension and Seal housing	1	See Drawing
		Sub-assembly		
	RO-1-1065-B	Flange - Gas Inlet	1	SST
	RO-1-1068-C	Shield Plug	7	See Drawing
	RO-1-1076-B	Instrument Hole Plug	1	See Drawing
	RO-1-1077-C	Instrument Thimble	1	Alum.
	RO-1-1097-E	Janus Core Buffer	1	See Drawing
	RO-1-1098-C	Flange-Core Buffer Gas Lines	1	See Drawing
	RO-1-1140-C	Shielding Plug	2	See Drawing
	RO-1-1100-C	Track Rotating Plug Rollers	1	SST
	RO-1-1117-C	Roller Assembly	3	See Drawing
	RO-1-1150-D	Top Shield Plug-Cooling Coil	1	SST
	RO-1-1153-C	Graphite Compartment	1	Alum.
	RO-1-1154-C	Large ("O" Ring Groove)	1	See Drawing
		Shielding Guide and Hold-Down		
		Plug		
	RO-1-1155-C	Detail Shielding Plug	2	See Drawing
		"O" Ring Groove		
	RO-1-1110-C	Small Shielding and	5	See Drawing
		Hold-Down Plug		
	RO-1-1111-C	Large Shielding and Hold-Down		
		Plug	1	See Drawing

DATE | CHANGE | SYM | DATE | CHANGE | SYM | DATE | CHANGE | SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1075 B/M (**BILL OF MATERIAL**)

PREPARED BY R. Smith | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1075-D	Tube Extension and Seal Housing Sub-Assembly		
1		Linear "O" Ring 2.362 ID x 2.568 OD x .103 TK	2	Neoprene
2		3/8-16 UNC x 1" Lg. Hex. Socket Hd. Cap Screw	4	SST
3		7/8-9 UNC x 1-3/4 Lg. Hex. Hd Semi-finished Bolt	8	SST
4		Washer 7/8 - plain	8	SST
5		1/4-20 UNC x 1-1/4 Lg. Hex. Socket Hd. Cap Screw	8	SST
6		Flexitallic Gasket Style D 10-13/16 ID 12-1/2 OD .175TK	1	SST & Teflon Filler
7		1/2-13 UNC x 1-3/8 Lg. Hex Hd. Semi-finished Screw	4	SST
8		1/2" Washer Plain	4	SST
	RO-1-1078-C	Pneumatic Extension Tube	1	Alum.
	RO-1-1079-B	Seal Compression Ring	1	SST
	RO-1-1081-C	Seal Housing	1	SST
	RO-1-1082-B	Seal Housing Couplings & Plate	1	SST
	RO-1-1085-A	Seal Rings	2	Teflon
	RO-1-1086-C	Pneumatic Sample Tube	1	Alum.
	RO-1-1087-C	Liner for Pneumatic Extension Tube Housing	1	See Drawing
	RO-1-1088-C	Shielding for Pneumatic Extension Tube Housing	4	See Drawing

DATE | CHANGE | SYM
DATE | CHANGE | SYM
DATE | CHANGE | SYM

ARGONNE NATIONAL LABORATORY RO-1-1089 B/M (BILL OF MATERIAL)

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

PREPARED BY J. Moudry | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1089D	Outer shield plug assembly rabbit facility	1	
	RO-1-1090D	Sample tube liner & housing	1	See Drawing
	RO-1-1091B	Sample tube flange joint	1	See Drawing
	RO-1-1092C	Source tube shield plug liner	1	See Drawing
	RO-1-1093C	Source tube shield plug	1	See Drawing
	RO-1-1094D	Outer shield plug	1	See Drawing
1		1½" NPS 150 lb. slip-on flange tube turn or equivalent	1	SST
2		½-13 NC x 2" long std. hex. head bolt and washer	4	SST
3		Flexitallic gasket CG-IF 2" ID x 2-3/4" OD	1	SST with Teflon insert
4		Flexitallic gasket CG-IT 14½" ID x 16" OD	1	SST with Teflon insert
5		1-8 NC x 2-3/4" long std. hex. head bolt and washer	8	SST
6		5/8-11 NC x 1-3/4" long soc. hex. bolt and washer	4	SST
7		"O" ring-Linear #11-224 1-3/4 x 2" OD	1	Neoprene
8		Flexitallic gasket CG-IF 2" ID x 2-3/4" OD	1	SST with Teflon insert
9		Flexitallic gasket CG-IQ 8-7/8 ID x 10-3/8 OD	1	SST with Teflon insert
10		"O" ring Linear #11-229 2-3/8 ID x 2-5/8 OD	2	Neoprene
11		5/8-11 NC x 1-3/4 long Hex. head bolt and washer	8	SST

DATE	CHANGE	SYM

CLASS	
MANU-FACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1101 B/M **(BILL OF MATERIAL)**

PREPARED BY R. Smith | APPROVED BY | SHEET 1 OF 2 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT			MATERIAL DESCRIPTION
	RO-1-1101-D	Converter Plates Drive Assemb.	1	*		
1		Janette Elec. Motor-½ Hp. 800-1 gear ratio, Model R-13 Polyphase, Frame PS, Foot-Mounting-Fig. 5181, Position 123		1		St'd
2		Janette Elec. Motor-½ Hp.800-1 gear ratio, Model R-13, Polyphase, Frame PS, Foot-Mounting-Fig. 5181 Position 126A		1		St'd
3		Hillard Slip Coupling, Size 8 Double Pl. Type 322, Bores of 1½ Dia.		2		St'd
4		Dodge SC Ball Bearing Pillow Block (for a 1½ Dia. Shaft) Non Expansion Type		4		St'd
5		Graphite Bronze Bushing Pillow Block American Stock Gear Co. #KR5 (for 1½ Dia. Shaft)		11		St'd
6		Hardened Steel Miter Gear Ratio, Boston Gear Cat. # HLK107Y		2 Pr.		St'd (Pur.Req.#571468)
7		3/8 x 3/8 x 2-7/16 Lg. Key		4		SST
8		3/8 x 3/8 x 1-1/2 Lg. Key		8		SST
9		3/8-16UNC x 1-1/8 Lg. F. Hd. M.S.		32		SST
10		5/8-11 UNC x 5/8 Lg. Full Dog Set Screw		4		SST
11		1/2-13UNC x 1¼ Lg. Hex. Hd. Bolt		12		SST
12		½-13UNC x 1½ Lg. Hex. Hd. Bolt				SST as Req'd
13		½-13UNC x 2¼ Lg. Hex. Hd. Bolt		18		SST
14		½-13UNC Hex. Hd. Nut		18		SST
15		½-13UNC x 5/8 Hex. Hd. Bolt		4		SST
16		¼-20UNC x 1" Cg. R. Hd. M.S.		12		SST
17		¼-20UNC Hex. Nut		12		SST
18		¼-20UNC x 1½ Lg. R. Hd. M.S.		4		SST
	RO-1-1104-B	Converter Plates Drive Shafts		2	*	SAE 3135 St.
19		Truarc Retaining Ring Cat. #5100-100 External			2	St'd
20		Truarc Retaining Ring Cat. #5100-150 External			2	St'd
21		1" ID x 2" OD x .187 Th'k Washer			2	Steel
22		¼ x ¼ x 3/8 Lg. Key			2	SST
23		Boston Gear Cat. #GD-27			2	St'd
	RO-1-1106-C	Converter Plates Line Shafts		1	ea.	SAE 3135 St.
	RO-1-1107-C	Converter Plates Wire Rope Drums		2 ea	*	SST
24		St'd. Bottom Swage Fitting for ¼" Dia. Wire Rope			4	SST

DATE	CHANGE	SYM	DATE	CHANGE	SYM	DATE	CHANGE	SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1101 B/M cont. **(BILL OF MATERIAL)**

PREPARED BY	APPROVED BY	SHEET	PROJECT ENGINEER	PROJECT NAME
R. Smith		2 OF 2	McCorkle	Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION
	RO-1-1105-B	Converter Plates Wire Rope Drum Face Plates	8		St.
	RO-1-1108-C	Pillow Block Supports			St. See Drawing
	RO-1-1102-B	Converter Plates Drive Motor Mt'g. Brk't.	2		St.
	RO-1-1122-B	Cable Drum Pillow Block Supports	4		St.
	RO-1-1121-D	Converter Plates Wire Rope Drum Cover	4		St.
	RO-1-1103-C	Converter Plates Drive Stops	2	*	Noted
25		Spur Gear-Boston Gear #GD84		2	St'd
26		Oilite Bearing - Cat. #AA-1043-6		2	St'd
27		Oilite Bearing-#AA-1704-20		2	St'd.
28		Truarc Retaining Ring #5100-75 (External)		8	Steel
29		Micro Switch (Honeywell Reg. Co.) #DTF		4	St'd
30		Thrust Washer-1½ ID x 3½ OD x 3/16 Th'k	8		Oil-Impregnated Bronze
	RO-1-1125-B				
31		Spacer 1/16" Th'k		8	Oil-Impregnated Bronze
32		1/8" Dia. x 1¼" Lg. Cotter Pin		8	St.

DATE	CHANGE	SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1128 B/M (BILL OF MATERIAL)

PREPARED BY H. Cern | APPROVED BY | SHEET OF | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1128-D	Janus - High and Low Level Shutter Assembly	*	See drawing
1		Hex. Hd. Bolt - 3/4" - 10 UNC x 9" long	8	304 SST
2		Hex. Hd. Bolt - 3/4" - 10 UNC x 8" long	8	304 SST
3		Hex. Hd. Bolt - 3/4" - 10 UNC x 5 1/2" long	16	304 SST
4		Cot. Pin-3/16D x 2 1/2 Lg.	6	SST
	RO-1-1136-A	Washer	32	304 SST
	RO-1-1026-D	Center Section - 20" Thick Shutter	1	See drawing
	RO-1-1029-D	End Section - 20" Thick Shutter	1RH 1LH	See drawing
	RO-1-1030-D	Center Section - 10" Thick Shutter	1	See drawing
	RO-1-1031-D	End Section - 10" Thick Shutter	1RH 1LH	See drawing
	RO-1-1132-C	Guide - 20" Thick End Section Shutter	1LH 1RH	See drawing
	RO-1-1133-C	Guide - 10" Thick End Section Shutter	1RH 1LH	See drawing
	RO-1-1048-B	Clevis-20" Th'k Shutter	3	Mild St'l
	RO-1-1049-B	Clevis-10" Th'k Shutter	3	Mild St'l
	RO-1-1146-B	Pin & Washer-Shutter Ass'y	6	See drawing

DATE | CHANGE | SYM
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DATE | CHANGE | SYM

CLASS	
MANU-FACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1149 B/M **(BILL OF MATERIAL)**

PREPARED BY R. Smith | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1149-F	Floor Shield Blocks	*	See drawing
1		Air Cyl. - See Purchase Order #336226	6	See purchase order
2		3/4"-10 UNC x 3" Lg. Hex. Hd. Bolt	48	St.
3		1"-8 UNC x 3" Lg. Hex. Hd. Bolt	24	St.
	RO-1-1165-C	Split Ring for Air Cyl. Flange	12	St.
	RO-1-1175-D	Floor Shield Bl'ks. Details	1	See drawing

DATE	CHANGE	SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1159 B/M (**BILL OF MATERIAL**)

PREPARED BY J. Moudry | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT			MATERIAL DESCRIPTION
	RO-1-1159-D	Helium Gas Catalyst Chamber	1	*		
1		Gasket - 4 1/8 ID x 5 1/4 OD		1		St. Stl. & Teflon
		Style "D" without Centering Guide				
		Flexitallic #D-1K				
2		Hex. Hd. Bolt-1/2-13 x 2"		6		Stl.
3		Hex. Nut 1/2-13		6		Stl.
4		Washer - 1/2 Plain		6		Stl.
5		Screen-4 11/16 dia. x 1/16 thick		1		St. Stl. Mfg. Std.
		with 1/16 dia. holes-Harrington-				
		King or Equiv.				
	RO-1-1160-C	Shell - Inlet		1	*	St. Stl.
1		Flange-1" -150# Welding Neck			1	St. Stl.
	RO-1-1161-A	Thermocouple Well			1	#304 St. Stl.
	RO-1-1162-D	Shell-Outlet		1	*	St. Stl.
1		Flange -1"-150# Welding Neck			1	St. Stl.
2		Union- 1/2" Socket Type			1	St. Stl.
	RO-1-1161-A	Thermocouple Well			1	#304 St. Stl.
	RO-1-1163-C	Catalyst Chamber		1	*	St. Stl.
1		Screen 1 1/2" Nominal Dia. x			1	St. Stl. Mfg. Std.
		1/16 thick with 1/16" Dia holes				
		Harrington-King or Equal				
2		Screen-Cylindical-nominal			1	St. Stl. Mfg. Std.
		Dia. 1 1/2" x 5 3/16 Long Mat				
		Thickness 1/16" with 1/16" Dia.				
		Holes Harrington-King or Equiv.				
	RO-1-1164-B	Drain Detail		1		SST
		Note: Stainless Steel may be				
		#304, #316, #321 or #347				
		unless otherwise specified.				

DATE | CHANGE | SYM | DATE | CHANGE | SYM | DATE | CHANGE | SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1181 B/M (BILL OF MATERIAL)

PREPARED BY R. Smith | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1182-C	5" Pipe Screen Assembly	*	
1		Eccentric Reducer - Nom Pipe 5" x 3" (St'd. Weight)	2	SST
2		Nom. 3" Pipe (150#) Slip on Flange	1	SST
3		Nom. 5" Pipe (150#) Slip on Flange	1	SST
4		Nom. 1/8" Solid Pipe Plug	1	SST
5		5-13/16" ID x 7" OD Flexitallic Style D Gasket	1	SST with Canadian-Asbestos Filler
6		3-3/4" ID x 4-3/4" OD Flexitallic Style D Gasket	1	SST with Canadian-Asbestos Filler
7		3" ID x 3-1/2" Style 920 (Type J) Goetze Gasket	1	Alum with Asbestos Millboard Filler
8		3-1/4" ID x 5-1/4" OD x 1/8" Th'k Ring	1	Aluminum
9		5/8-11UNC x 3-3/4 Lg. Hex. Hd. Bolt	4	SST
10		5/8" Plain Washer	4	SST
11		5/8"-11UNC Hex. Nut	4	SST
12		5/8" Split Lock Washer	4	SST
13		3/4"-10UNC x 4" Lg. Hex. Hd. Bolt	8	SST
14		3/4" Plain Washer	8	SST
15		3/4"-10UNC Hex. Nut	8	SST
16		3/4" Split Lock Washer	8	SST
	RO-1-1181-C	Screen & Housing	1	Noted
17		Nom. 5" Pipe (150#) Slip on Flange	1	SST

DATE	CHANGE	SYM

CLASS	
MANU-FACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1188 B/M **(BILL OF MATERIAL)**

PREPARED BY R. Smith | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT	MATERIAL DESCRIPTION
	RO-1-1188-D	Air Cyl's Piping Detail	* 1	
1		1-1/4 Nom. size type-K tubing	As Inst.	Copper
2		1-1/4 Sch. 40 Pipe	As Inst.	SST
3		1-1/2 Sch. 40 x 1-1/4 Lg. pipe	6	SST
4		1-1/4 Pipe Nipple	12	SST
5		1-1/4 Pipe Coupling	12	SST
6		1-1/2" x 1-1/4" St'd Concentric Pipe Reducer	6	SST
7		1-1/2" 90° Street Elbow	6	SST
8		1-1/4 x 1-1/2 (M.S.P.S.) Male Adapter Copper to M.S.P.S.	6	Copper or Brass
9		1-1/4 Nom. Size 90° Elbow Copper to F.S.P.S.	6	Copper or Brass
10		90°Elbow (Close-Ruff) Copper to Copper	6	Copper
11		90°Union Elbow (F.S.P.S.E.11 to Copper Tailpiece)	24	Copper or Brass
12		Union Copper to Copper	4	Copper
13		45° Elbow Copper to Copper	2	Copper
14		12" Dia. Air Cyl's.	12	As Instructed

DATE | CHANGE | SYM | DATE | CHANGE | SYM | DATE | CHANGE | SYM

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1220 B/M (BILL OF MATERIAL)

PREPARED BY H. Cern | APPROVED BY | SHEET 1 OF 1 | PROJECT ENGINEER McCorkle | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION
	RO-1-1220-E	Rod Drive Assembly	1	*	
1		Hex Hd. Bolt - 1/2 - 13UNC x 1-1/2		8	316 SST
2		1/2 - Plain Washer		8	304 SST
3		3/8 Dia. x 1-1/4 Lg. Dowel Pin		2	304 SST
4		Hex. Nut - 3/8-16 UNC		8	304 SST
5		Hex. Hd. Bolt 3/8-16 UNC x 1-3/4 Lg.		8	316 SST
6		3/8 - Plain Washer		16	304 SST
7		Teleflex Inc. - Control Rod Drive Unit - Mfg. Drawing No. 18506		1	Mfg. St'd (P.O. No. 309495)
	RO-1-1218-C	Pulley Housing Mounting Bracket		1	6061 Alum.
	RO-1-1219-C	Motor Drive - Mounting Bracket		1	See drawing

DATE	CHANGE	SYM
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DATE	CHANGE	SYM

CLASS	
MANU-FACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

ARGONNE NATIONAL LABORATORY RO-1-1259 B/M (BILL OF MATERIAL)

PREPARED BY	APPROVED BY	SHEET	PROJECT ENGINEER	PROJECT NAME
H. Cern		1 OF 1	A. Pierce	Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION
	RO-1-1259-D	Modified Janus Safety Rod Drive	2	*	See Drawing
1		Gear Motor - Janette Electric Mfg. Co. type C-12 120V AC, single phase .87 RPM output 195 lb. in torque, 1/125 Hp cont. duty reversible, enclosed. Current rating = .45 amps. Shaft to be toward right facing gear box - foot mounted.		2	Mfg. St'd. (P.O. No. 596241)
2		Clutch Coupling - Warner Electric Brake & Clutch Co. Beloit, Wis. Clutch coupling ball bearing mounted #SF160 Rotor hub bore 1/2" Dia. Arm hub bore 1/2".		2	Mfg. St'd.
3		Drive Box Assembly - 18506 - Teleflex Inc. North Wales, Pa.		2	Mfg. St'd
4		Mech-Stop Assembly - Teleflex Inc., North Wales, Pa.		2	Mfg. St'd.
5		Gear - Atlas Precision Product Co., Philadelphia, Pa. 48P - 24T - 20°P.A. - 500PD. Cat. #CG 4747-24.		2	Mfg. St'd.
6		Gear - Atlas Precision Co. Philadelphia, Pa. 48P - 72T - 20°P.A. 1.500 PD. Cat. #CG 4727-72.		2	Mfg. St'd.
7		Shaft Hanger - Beckman Helipot Corp. Newport Beach, Calif.		4	Mfg. St'd
8		Shaft Collar - Beckman Cat. #BP-211-E or equivalent.		4	Mfg. St'd
9		Shaft - Beckman Cat. # BP-125-148 or equivalent		4	Mfg. St'd.
10	A	Limit Stop - Beckman adjustable cam assembly - Cat. No. BP-537-2 or equivalent		12	Mfg. St'd. See Drawing RO-1-1276-A
11		Micro Switch - Micro Switch Cat. #DT-2RV23-A7 (DPDT)		12	Mfg. St'd.
12		Shaft Coupling - 1/4 Dia. x 3/4		4	Boston Gear or equiv.
13		Aluminum Angle - as per Teleflex Dw'g #18506-81		16	6061 T6 Alum.
14		Potentiometer - Clarostat Type 42JA - 1000 ohm		4	
15		Receptacle-# 973102A-28-21P49C		2	Mfg. St'd
16		Plug - Amphenol - AN-3106 A28-21P W/AN3057-16 Cable Connector		2	Mfg. St'd
17		Angle - As per Teleflex Drawing Number 18506-80		8	6061T6 Alum.

DATE	CHANGE	SYM
	Modified Cam	A

ARGONNE NATIONAL LABORATORY RO-1-1260 B/M (BILL OF MATERIAL)

CLASS	
MANUFACTURED	M
PURCHASED SPECIAL SPEC.	P
PURCHASED COMM. RAW	R
PURCHASED ARGONNE FINISH	A

PREPARED BY B. Garbelman | APPROVED | SHEET 1 OF 1 | PROJECT ENGINEER A. Pierce | PROJECT NAME Janus Reactor

ITEM	PART NUMBER	PART NAME	REQ. PER UNIT		MATERIAL DESCRIPTION
	RO-1-1260-E	Modified Janus safety-regulating drive mechanism assembly	1	*	See Drawing
	RO-1-1259-C	Modified Janus safety rod drive		2	See Drawing
	RO-1-1249-D	Modified Teleflex Corp., Janus safety rod pulley box assembly			See Drawing
	RO-1-1218-C	Pulley housing mounting bracket		2	See Drawing
	RO-1-1219-C	Motor Drive Mounting bracket		2	See Drawing
1		Cap screw 5/8"		4	ST.
2		Washer		4	ST.
3		3/8" Dia. x 1" Dowel pin		2	ST.
4		Janus reg. rod drive See Teleflex Dwg. #18506, Sheet 1 and 18506 B/M		1	

DATE | CHANGE | SYM

C. Maintenance and Operating Instructions

1. Instrumentation

a. Nuclear Instrumentation

(1) RJC-9 Nickel-Cadmium Battery (Care and Maintenance)

The RJC-9 nickel-cadmium battery is a 5-cell, 7.2 v battery. The electrolyte is KOH (purified caustic potash) dissolved in distilled water, giving a specific gravity between 1.180 to 1.220 at 72°F or 22°C. The discharge gas contains entrapped potassium hydroxide which combines with carbon dioxide in the air to form potassium carbonate which is a noncorrosive, inert white powder. It is electrically conductive when damp; therefore, if allowed to build up as a deposit between terminals, it could cause current leakage and possible discharge of the battery. Therefore, any accumulation should be removed with brush or damp cloth.

The cell vent caps should be kept closed at all times except when adding water or checking the electrolyte, and this should always be done as quickly as possible, opening only one vent cap at a time.

During charge or discharge of a nickel-cadmium battery, there is practically no change in specific gravity of the electrolyte. The sole function of the electrolyte is to act as a conductor for the transfer of hydroxide ions from one electrode to the other, depending on whether the cell is being charged or discharged.

Distilled water should be added to within $\frac{1}{2}$ to 1 in. above plate tops. The electrolyte test tube should be used to measure level. After distilled water is thoroughly mixed with electrolyte, note specific gravity of cells. It should read between 1.180 to 1.220 at 72°F or 22°C.

Nickel-cadmium batteries use very little water when they are on float or trickle charge at a voltage equal to 1.44 times the number of cells.

Cells should never be overfilled; the electrolyte will be forced out of the vents on charge and saturate the trays, causing electrolysis between cells and causing troublesome grounds in the electrical circuit. It will dilute the electrolyte to such an extent that the specific gravity will become too low and damage the plates.

Do not use water that is ordinarily added to lead storage batteries for nickel-cadmium batteries. It generally contains small amounts of sulfuric acid. Use pure distilled water free of any impurities that might become cumulative over the years.

The batteries all contain a $\frac{1}{4}$ -in. layer of oil floating on top of electrolyte, which retards the natural evaporation of water from electrolyte. It is a pure, acid-free, nonsaponifying oil. Only such oil should be used if the need arises.

Always return a sample of electrolyte to the cell from which it was taken. After use, wash out the hydrometer thoroughly with water to remove all traces of electrolyte, as any electrolyte allowed to remain in the hydrometer will absorb carbon dioxide from the air to form a thin coating on the float, which will cause a false reading. Impurities of all kinds must be kept out of the cells, as they have a harmful effect and can eventually ruin the batteries. Sulfuric acid can ruin a nickel-cadmium battery by attacking and corroding the steel plates and cell containers. To prevent contamination, never use any tools or utensils such as hydrometer funnels, battery fillers, etc., which have been used for servicing lead storage batteries.

Any vegetable oil or grease introduced into the cell will cause them to froth on charge.

Fully charged batteries floated across the line should be maintained at a voltage equal to 1.44 times the number of cells in the battery; otherwise, the battery will become slowly discharged and require overcharge from time to time to bring it back to a fully charged condition.

The battery charger for the "Janus" electronics galvanometer circuit is a silicon bridge rectifier type. The charger is adjustable for the correct voltage to each cell (1.44 v) by changing the switch on the chassis for increasing or decreasing voltage to battery. Periodic checks should be made to see that the battery is maintaining its charge, discharging, or overcharging. Too high a charge current will cause cells to gas and hence consume water. Too low a charge causes a battery to lose its usefulness.

To determine the state of charge of a battery, the open-circuit voltage reading (no current being delivered) cannot be used as an indication. The specific gravity of the electrolyte does not indicate its state of charge. The state of charge of a partially charged battery must be made by reading current and voltage simultaneously.

The best method is to use an accurage voltmeter (1% or better) and insert an artificial load equal in value to the normal load. Voltage readings obtained while the battery is connected momentarily to the artificial load indicates the condition of the battery. A 3-amp load will be normal for the "Janus" electronic galvanometer circuit. An approximately 2.35-ohm resistor can be used to determine state of charge.

The electrolyte is injurious to skin and clothing; therefore, it should always be handled carefully. A supply of concentrated boric acid (solution 5 oz of boric acid powder to each quart of water) should be kept handy for neutralizing any accidental splashes on persons or clothing.

The electrolyte level should be checked every six months under normal condition: $\frac{1}{2}$ to 1 in. above top of plates is the correct level.

(2) <u>Log N and Period Channel</u>
(Model CD 180)

INSTALLATION

The Log N preamp unit should be mounted within a short cable length of the ion chamber, preferably no more than 20 ft. It should be mounted in such a manner that it is not electrically grounded. The ion chamber should also be insulated from ground. Ordinary types of insulating materials are adequate for isolating these items from ground.

The cable from the chamber collector to the CURRENT INPUT of the Log N preamp should be a graphite-coated type, with Teflon-insulated connectors carefully assembled and cleaned. It should be located in such a position that it will not be subject to mechanical shocks or vibration which could produce a false period trip. The positive and negative voltage connections to the chamber may be ordinary non-graphite-coated coax. Teflon connectors are not required. The two voltage cables should be positioned near the current signal cable, preferably taped together every few feet, and routed through the connections provided on the Log N preamp.

The multiconductor cable between the Log N preamp and the main chassis should be a shielded cable with the shield braid tied to the connector shell at both ends. The voltage connections from the preamp box to the high-voltage supplies should be routed along with the multiconductor cable.

The chamber-voltage supplies should be mounted adjacent to the main chassis, and there should be a good electrical connection between the two chassis provided by a braided ground strap.

OPERATION AND ADJUSTMENTS

If a remote period meter is not used, it is necessary to short terminals 3 and 4 on the barrier strip to obtain indication on the panel PERIOD meter. Also, if a remote current-indicating meter is not used, it is necessary to short terminals 11 and 12 on the barrier strip to make the panel CURRENT meter operate.

The INPUT LEVEL ZERO is adjusted by shorting across the diode string and adjusting for zero voltage as measured between T_3 collector and ground. Normally, this adjustment will be required very infrequently, if at all.

The CURRENT meter may be calibrated by means of the LEVEL and SPAN controls. This calibration requires operating the TEST CURRENT switch on the preamp while observing a meter on the main chassis. Although it can be performed with two people, or with several trips between locations, it is recommended that the preamp be dismounted and taken to the location of the main chassis and connected by means of an auxiliary short cable. Calibrate as follows. With the CURRENT INPUT cable disconnected and the preamp connector capped, set the TEST CURRENT switch on 10^{-5}. Observe the CURRENT meter and adjust LEVEL for a correct reading. Then switch the TEST CURRENT to 10^{-9}. If the CURRENT meter reads high, the span between the two test currents is too small. In that event, turn the SPAN control clockwise a small amount - disregard the change in meter reading while making this adjustment. The LEVEL may then be readjusted to give correct indication of 10^{-9} amp, and the 10^{-5}-amp level may be rechecked. If still not correct, repeat the procedure until the meter reads right at both current levels.

The ZERO adjustment should be set for zero voltage from T_7 collector to ground with the RECOVERY button held down.

After properly setting the ZERO, the ∞ ADJUST should be set for an infinity reading on the period meter with the RECOVERY button held depressed (if it makes a difference).

The TRIP LEVEL may be set by first turning the PERIOD TEST switch ON and setting the PERIOD TEST SIGNAL control to give the desired period indication. Turn the TRIP LEVEL to its clockwise maximum and press the RESET. Then turn the TRIP LEVEL back from the clockwise limit until a trip occurs and leave it at this point.

OVERALL CHECK

The instrument is self-checking by means of the TEST CURRENT signal on the Log N preamp, and the PERIOD TEST SIGNAL on the main chassis. The latter may be used as a check on the performance of the amplifier consisting of V_2, T_5, T_6, and T_7, and also on the performance of the trip circuit. If the PERIOD TEST SIGNAL will provide readings over the complete range of -10 to 10 sec, the amplifier is very probably in good working order. If the trip circuit functions as the PERIOD TEST SIGNAL is advanced to the level corresponding to the TRIP LEVEL setting, the trip circuits are very probably in good order.

The Log N preamp circuit may be checked by two tests. First, see if the CURRENT meter reads correctly at both test current levels of 10^{-5} and 10^{-9} amp. Second, disconnect the CURRENT INPUT cable and cap the connector on the preamp. When the current signal is switched off from 10^{-9} amp, the CURRENT meter reading should go below the low end of the scale. If both tests are satisfactory, the Log N preamp is very probably in good shape.

It will be noted that during certain testing operations, such as turning the TEST CURRENTS on, the PERIOD meter will remain pinned at one end or the other for some period of time. This is normal, for such signals overdrive the amplifier-following capacitor C, and the capacitor then discharges with a long time constant. The meter will eventually recover of its own accord if sufficient time - perhaps several minutes - is allowed. If a quicker recovery is desired, it is only necessary to press the RECOVERY button.

In a similar manner, it will be noted that other operations, such as turning the high-voltage supplies on or off when connected through the chamber to the input of the Log N preamp, will result in a below-scale reading on the current meter, even at times when the current level is known to be above 10^{-11} amp. This is caused by a similar effect in the Log N circuit, where the input capacity to ground has developed a transient charge and it is required to leak off through the high resistance of the diode string. This circuit will also eventually recover on its own accord, though it may require several minutes. If a quick recovery is desired here, the TEST CURRENT switch may be turned to 10^{-5} amp. The current meter should come up to that reading almost immediately. Then, when the switch is turned off, the meter should drop to its correct reading.

If further information about the theory of operation of a period meter is desired, see DC REACTOR INSTRUMENTS, Electronics Division drawing EL 2523.

b. Non-nuclear Instrumentation

Installation, maintenance, and operating instructions are provided for specialized equipment by the manufacturer's booklets and manuals listed in Section VII.

2. Cooling Systems

a. Primary Cooling System

The primary cooling system is normally a closed system with its own controlled atmosphere. The problems associated with its establishment and maintenance are considerably different than for the secondary cooling system and should be discussed separately.

(1) Filling the System

The primary cooling system, exclusive of the storage tank, will contain about 550 gal of deionized water when it is filled. The water level in the reactor tank will then be at the 5-ft mark. The shell sides of the heat exchangers, the pump casings, the cleanup system, and all connecting piping of the primary cooling system and its auxiliaries will also be full. Approximately 10 gal of additional deionized water should be put in the storage tank.

Inventories of water additions to the reactor tank and the storage tank should be kept when they are being filled for purposes of calibrating the level indicators which are associated with these tanks. The reactor uses ion-free or deionized light water while operating and also as a final step in the processes of cleaning the interior of the primary cooling system. It is, thus, not essential to dry the primary cooling system before filling it with the reactor water, as in the case of a reactor which operates with heavy water for the moderator-coolant, except to insure accuracy in calibration of the level indicators.

The calibrations, preferably, should be carried out when convenient during the process of cleaning the system and preparing the reactor for the loading in of the final charge of deionized water.

Let us assume the primary cooling system is thoroughly cleaned and that the water-level indicators for the reactor tank and the storage tank are calibrated.

To fill the primary cooling system, a supply of deionized water totalling approximately 560 gal should be on hand or readily available. If the deionized water is received in drums, an arrangement should be provided for attaching between the drums and a small valve fitted to a flange in the 3-in. suction line of the primary coolant-circulating pumps. The water may be added here and run to the storage tank. If the quality of the deionized water is doubtful, the loading into the storage tank may be accomplished by connecting the supply drums to a small valve at one of the water-sampling stations of the cleanup system. In this way, the water may be run through the mixed-bed resin column of the cleanup system before entering the storage tank. The conductivity of the water entering the tank may be monitored at the cleanup system. The deionized water, may if desired, be obtained at a smaller supply rate from the still line of Building 202. Either location for adding to the storage tank may also be employed in this case.

After the approximately 560 gal of reactor water have been placed in the storage tank and the pump section of the system, the isolation valves for the primary circulation pumps should be set slightly open. Start the pumps one at a time and run them briefly. When it is sure the pump cases are free of gas, stop the pumps and close their isolation valves.

Now, open slightly the isolating valves for one of the circulating pumps and start the pump. Slowly direct the water from the storage tank through the heat exchanger and into the reactor tank. When the gas has been displaced from the heat exchanger and water is running into the reactor tank, restrict the flow through the throttle valve PV-5 of Fig. 31 by reducing its opening. Open valve PV-2 of the above Fig. 31 until the suction line running to the reactor is filled and water runs from it into the reactor tank. Now open valve PV-5 slightly more, and continue pumping water from the storage tank into the reactor tank via both lines until the desired level (5 ft or less) is attained. Now, close valves PV-2 and PV-1. Adjust the isolating valves at the suction and discharge ends of the pump, and regulate the throttle valve PV-5 to obtain the desired flow and pressure in the heat exchanger. The auxiliary parts of the primary system should now be adjusted for the desired flows. The primary cooling system is now in normal operating condition.

(2) Maintenance of the System

The primary cooling system should require very little attention to maintain the proper operation. It is anticipated that occasionally the mechanical seal of the pump may need to be replaced. A circulating pump may be isolated and removed for repair by closing the appropriate isolating valves and unbolting connecting flanges. An exhausted resin column may be removed and replaced through use of similar arrangements. Isolating valves and connecting flanges are provided in most parts of the system where component failure may require repair or replacement.

b. Secondary Cooling System

The secondary cooling system includes the tube sides of the heat exchangers for removing heat from the primary cooling system, the secondary cooling pumps, the cooling tower, a flow meter, pressure and temperature indicators, isolating and throttle valves, and connecting piping. All of these components are standard commercial units and will require the usual attention given for heat removal systems having similar surroundings.

(1) Filling the Secondary Cooling System

Laboratory water may be added to the cooling tower via the make-up line to supply the level recommended by the manufacturer of the cooling tower. The circulating pumps may be flooded and primed in a normal fashion by use of appropriate valves. The flow may be started and adjusted by normal procedure as needed for the associated reactor operation.

(2) Maintenance of the System

Since this system is not a closed system, it is subject to accumulation of dirt, scale, etc. Evaporation from the cooling tower will cause increase of mineral content and will require water treatment. Use of chemicals, blow down, and mechanical or chemical cleaning will probably be required to keep this system in proper condition. Wear on pump seals will be greater in this system than in the primary cooling system; consequently, more frequent inspection and replacement will be necessary.

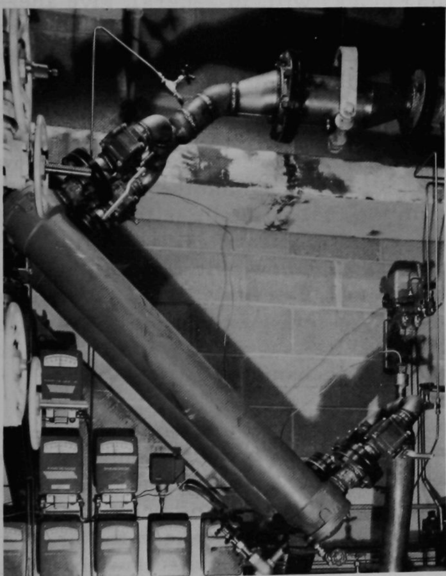

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Fig. 81. Main Heat Exchangers for "Janus" Reactor

The heat exchangers will acquire film and other undesirable coatings on the inner surfaces of the tube sides. Consequently, the heat exchangers have been installed as shown in Fig. 81 so that mechanical or chemical cleaning of the tubes may be accomplished in a relatively simple fashion.

3. Servicing Control Rod Mechanisms and Changing Reactor Fuel

The safety rods and the regulating rod are arranged so that they will be inserted or run in upon shutdown of the reactor by scram action initiated by safety interlocks, scram buttons, and by turning the reactor power key switch to its off position. If a safety-rod mechanism or the regulating-rod mechanism has become sluggish, or a safety-rod group does not insert properly, or if it is desired to inspect or service the control-rod mechanisms, the following procedures are recommended.

a. Shutdown of the Reactor

The reactor may be secured in shutdown condition by the insertion of safety rods and the regulating rod to their in positions. The reactor water temperature should then be leveled off at approximately 25°C by continuing use of the circulation pumps and the cooling tower for about 30 min after reactor shutdown. By this time, the release of fission product decay heat following continuous 90-day full-power operation of the reactor will be at a rate not greater than 500 w for the hottest fuel assembly. At this heat-generation rate, the temperature increase of the reactor, without external cooling, will be about 0.05°C/min.

After the reactor has been cooled to 25°C, removal of the 10-ton biological shield blocks at the top of the reactor may be started. Removal of three of five such shielding blocks will, in general, give adequate access to the safety- and regulating-rod mechanisms, and to the top of the reactor vessel. The reactor will have been shut down for approximately one hour by the time this operation is completed.

At this stage, the hottest fuel assembly will be releasing fission product heat at a rate of about 250 w. The reactor water may now be pumped from the reactor tank to the storage tank and the pumps and valves secured. Radiation of heat from the fuel assemblies to the surrounding reactor structure will keep the fuel elements well below their melting temperature. The reactor will be far below critical with the water removed even if all the safety rods and the regulating rod were removed.

b. Servicing the Control-rod Mechanisms

When the safety- and regulating-rod mechanisms have been made accessible, the drive power for the safety rods should be turned off and their out-limit switches actuated manually, so that the regulating rod may be run part way out to servicing position. At this position, the union connection of the cable conduit may be opened to expose the regulating-rod stem. A clamp used in servicing the mechanism should then be tightened around the stem of the regulating rod and bolted to its shielding plug, which is bolted to the top of the reactor tank. This clamp holds the regulating rod so it cannot be run in or out.

The idler pinion of the regulating-rod mechanism should now be removed from its mount and the drive cable disconnected from the regulating-rod stem. A short cable for lowering the regulating rod to its in position should be attached to the stem, then the servicing clamp loosened, and the regulating rod lowered into the reactor to its completely down position. The top of the lowering cable will now be a short distance above the bottom section of the conduit union. The servicing clamp should be tightened to confine the regulating rod to its in position.

If the regulating-rod mechanism is to be cleaned or otherwise serviced, its components should now be removed from the top of the reactor and taken to a shop for attention as may be required. If no attention is required by the safety-rod mechanisms or by a fuel-loading change, the regulating-rod mechanism may be reinstalled in the reactor by reversing the steps followed in its removal. The biological-shielding plugs should then be restored to proper position and the reactor returned to normal operation.

If, however, a safety-rod mechanism is in need of servicing, the steps in the last two sentences of the paragraph immediately above should be omitted and the safety-rod group to be serviced should be handled in a manner similar to that for the regulating rod. With the regulating rod disconnected from its drive mechanism and inserted in the reactor as described above, attention should be given to preparing the indicated safety-rod group for servicing. The overrun tube should be removed from the safety-rod drive unit. A clamp should be installed around the overrun cable and attached to the drive sprocket housing. The safety-rod group should be driven part way out to the servicing position. The clamp should be tightened on the overrun cable so that the safety rod cannot be accidentally released or run into the reactor. The union connections on the cable conduits may be opened to expose the stems of the safety rods constituting the group to be serviced. A servicing clamp should be tightened around each stem and bolted to its shielding plug fastened in the top of the reactor tank. These clamps will hold each safety rod of a group so they cannot be run in or out.

The spring-loaded idler pinion assembly should then be removed, and its mount and the cables disconnected from the safety-rod stems. A short cable for lowering a safety rod to its in position may be attached to each stem; then, the individual servicing clamps may be loosened, one at a time, and the individual safety rods lowered into the reactor to their completely down positions. The tops of the lowering cables will be short distances above the bottom sections of the conduit unions. The servicing clamps should be tightened individually to confine the safety rods to their in positions. The components of the safety-rod mechanism to be cleaned, inspected, or otherwise serviced may be removed to a shop as required. Upon completion of the servicing operation, the safety-rod mechanism may be reinstalled in the reactor by reversing the steps followed in its removal. The regulating-rod mechanism should then be reinstalled as outlined above and the reactor returned to normal operating condition, unless another group of safety rods is to be serviced or the reactor fuel loading is to be changed. The same steps described above should be followed to service the additional safety-rod mechanisms and prepare the reactor for return to normal operation.

c. Changing Control Rods and Fuel Loading

If it is known that the poison section of a control rod must be removed for replacement or if it is desired to remove the poison section for inspection (which normally would require the use of cave facilities), or if for some reason the cap-and-stem portion of a control rod is made inseparable from the poison section of the rod, proceed by using a coffin for removal of an individual control rod. In beginning this procedure, the reactor is to be secured in the shutdown (greatly subcritical) condition provided when all control rods are fastened at their full-in positions as described in subsection b immediately above. The top of the reactor tank should be cleared of all attachments which would interfere with the positioning of the coffin and its aligning template or which might be damaged by impact of the coffin. The shielding plug for the selected control rod should be unbolted from the reactor top. The coffin-aligning template and its supporting frame should be properly located and secured to the I beams which support the top floor shielding blocks (see Fig. 63). Then, after connecting the cable running from the bottom of the coffin to the control rod and its attached shielding plug, the control rod and plug may be carefully drawn from the reactor into the coffin. At this point, the coffin gate should be closed and the loaded coffin removed. A special hold-down poison section should now be inserted in the control rod location and a solid shielding plug secured above it in the reactor top. The same procedure should be repeated for as many control rods as may need to be removed, inspected, or replaced. If a complete fuel-loading change is to be performed, the above procedure would be followed for all seven control rods if their stems are inseparable from the poison sections. The rotatable plug can then be manipulated to bring access parts in the plug to alignment with any desired fuel-assembly position. The seven fuel assemblies which contain the hold-down poison sections should, as a matter of practice, remain in the reactor core until all others have been removed.

The control rods and stems have been designed so that they may be separated one from the other by unscrewing small retaining bolts. If this arrangement is in use, a fuel reloading may be accomplished by following the procedure of Section IX.C.3.b to the point where all safety rods and the regulating rod have been secured at their completely in positions in the reactor. The top of the reactor tank should be cleared of all attachments which would interfere with the operation of fuel removal. An individual servicing clamp may be loosened, and the shielding plug above the corresponding control rod may be unbolted and removed from the reactor.* A special shielding plug carrying a long-handled Allen wrench should be inserted over the control-rod lowering cable and stem. By use of the wrench, the control-rod stem may be unbolted. The special shielding plug and wrench should be removed as well as the control-rod stem. A third solid shielding plug should be inserted above the control rod. The top of the control rod will now be a small distance below the bottom of the rotatable shielding plug above the core of the reactor. When all of the control-rod stems have been removed and the corresponding shielding plugs inserted one at a time, the reactor will be ready for use of a coffin for withdrawing any selected fuel assembly from the reactor or for a complete removal of all fuel assemblies, one at a time, into the coffin.

Subsequent reloading of the reactor may now be accomplished by reversing the unloading process if duplicate fuel assemblies are used. If, however, fuel assemblies of different uranium content or control rods of different arrangement from those originally used are to be employed, the procedure for the initial loading should be followed.

d. Alternative Procedure for Changing the Fuel Loading

If the safety and regulating rods and their associated mechanisms are performing properly so that they do not require servicing, but it is desirable to add fuel to increase reactivity, this may be accomplished by a relatively simple procedure.

Follow the procedure outlined above in subsection a. It is then possible to observe three smaller shielding plugs in the rotatable plug which are not used for safety- and regulating-rod installations. These three plugs are located directly over three fuel-assembly positions of the reactor core. In the design of the "Janus" reactor, it was intended that these positions should be occupied by dummy fuel assemblies or by type-two fuel assemblies, namely, those composed of inner and intermediate fuel-bearing cylinders with an outer cylinder of plain aluminum and a non-fuel-bearing thimble in the center of the assembly. Another fuel assembly, known as a type-one fuel assembly, has the outer, intermediate, and inner cylinders all fuel-bearing, but has a non-fuel-bearing thimble in the center of the assembly. Either of these assemblies may occupy the positions in the core which align with the smaller shielding plugs mentioned. The required arrangement will be determined at the initial loading of the reactor. If one or more of these three fuel positions contains a dummy or a fuel assembly with a non-fuel-bearing thimble, it is now possible to add fuel to the reactor quite readily as follows:

(1) Secure the control rods at their full-in positions, and clear the reactor top sufficiently to provide unimpeded access to the three smaller shielding plugs.

*See subsection d for Alternative Procedure for Changing the Fuel Loading.

(2) Remove the shielding plug over the position that corresponds to the assembly which will accommodate the fuel addition nearest in magnitude to the estimated amount needed for the desired reactivity change. (It should be noticed that two of the three shielding plugs are only large enough to allow removal or insertion of a central thimble. The third shielding plug is sufficiently large to accommodate a complete fuel assembly.)

Let us assume that the exchange of a fuel-bearing thimble for a non-fuel-bearing thimble will accomplish the desired reactivity change.

(3) Now, insert a thimble-handling tool through the selected small plug opening and attach it to the plain aluminum thimble. Loosen the thimble, by lifting it slightly by hand, then lower it back to position.

(4) Move the refueling coffin into position directly over the thimble-handling tool, and attach to the tool the lifting cable extending from the bottom of the coffin.

(5) Lower the coffin to provide adequate shadow shielding for the thimble to be removed. Steady the coffin by a suitable mechanical restraining device; then proceed to carefully draw the thimble into the coffin.

(6) After removal of the coffin, the fresh fuel-bearing thimble may be installed by hand through use of a thimble-handling tool.

(7) The weighted beryllium source section from the plain aluminum thimble or a new weighted source section should be installed in the new thimble.

(8) The fuel-changing operation is completed by reinstalling the shielding plug and restoring the reactor top and the floor shielding to operating condition.

A similar procedure would be followed for replacing one type of fuel assembly by another type through the largest of the three shielding plug positions.

D. General Reactor Facility Data

1. Operational and Related Data

Nominal Power Level	200 kw
Type of Fuel	U-Al Alloy; Uranium enriched to 93% in U^{235}

Moderator, Coolant	Light water
Type of Fuel Assembly	CP-5 type made of three concentric cylinders and a thimble. Fuel-bearing portions include from two to four cylinders
Number of Fuel Assembly Positions	19
Core Size	
Diameter	~41 cm
Height	~60.5 cm
Volume	~80 liters
Fuel Loading (Max.)	~4080 g
(U^{235}) (Min.)	~2700 g
Estimated Fuel Consumption (continuous full power)	~2 g/week
H_2O to Metal Ratio	2.51:1
Thermal Neutron Flux	
(n/cm²/sec) Maximum	4.5×10^{12}
Average	3.5×10^{12}
Temperature Coefficient of Reactivity	-0.061% $\Delta k/k/C°$
Void Coefficient	-0.2% $\Delta k/k$/% void
Reactivity Effect of Xenon (in Equilibrium at 200 kw)	-0.7% $\Delta k/k$
Maximum Excess Reactivity	1.5% $\Delta k/k$
Heat Transfer Data:	
Total Coolant Volume	2200 liters
Coolant Volume in Core	57.3 liters
Coolant Flow Rate	6.3 liters/sec
Average Coolant Velocity in Fuel Channels	15 cm/sec
Average Power Density	
Core	2.5 kw/liter
Core Coolant	3.5 kw/liter
Average Heat Flux	2.3 w/cm²
Operating Temperature of Core	~50°C

Converter Plates:	
High-dose Side	
Size	1.27 cm x 190 cm x 97.8 cm
U^{235} Content	6100 g
Low-dose Side	
Size	1.27 cm x 300 cm x 97.8 cm
U^{235} Content	9600 g
Irradiation Cells:	
High-dose Cell	
Size (approx)	244 cm x 488 cm x 305 cm
Maximum Dose Rate	~100 rads/min
Low-dose Cell	
Size (approx)	700 cm x 700 cm x 335 cm
Maximum Dose Rate	~0.01 rad/min

2. Cost Breakdown for the "Janus" Neutron Irradiation Facility

The costs involved in the purchase, fabrication, assembly, and other construction of the various items entering into the completed "Janus" Irradiation Facility are considered under two main groups. The Reactor, its Components, and its Operations Equipment form the larger and more complex group. The Building with its utilities and the ventilating and air conditioning equipment form the other group.

a. The Reactor, its Components and its Operations Equipment

(1) Shielding

(i)	Machined Lead Bricks	$ 9,188
(ii)	Lead Billets	4,233
(iii)	Lead Brick (other)	4,196
(iv)	Top Shield and Rotating Plug	10,493
	Top Shield Plugs (additional)	2,846
	Roller and Track for Rotating Plug	1,025
(v)	Floor Plugs and Normal and Dense Concrete	28,774
		$60,755

(2) Reactor Containment Shell

(i)	Reactor Steel Shell	$12,355
(ii)	Steel Forms between Building and Steel Shell	811
(iii)	Boral Sheets	3,360
(iv)	Pedestals for High- and Low-level Lead Walls and Shutters	4,715
		$21,241

(3) Graphite

(i) Graphite for Core Buffer	$ 7,154
(ii) Graphite for Reflector and Thermalizer	30,687
	$37,841

(4) Reactor Vessel, Components, and Equipment

(i) Reactor Vessel and Plenum	$ 8,193
Grid Plate and other Vessel Parts	1,265
Core Buffer	2,633
Leveling and Support Screws	264
(ii) Cooling Tower	8,274
(iii) Pumps	1,823
(iv) Heat Exchangers	1,227
(v) Coolant Storage Tank	500
(vi) Belt Guards	28
(vii) Skimmer Guide and Shield Plug	615
(viii) Repair Kit for Pumps and Valves	35
(ix) Pipe, Fittings, Valves, etc.	7,925
	$32,782

(5) Converter Plates and Drives

(i) Converter Plates (Fabrication)	$ 3,557
Analysis of Material	543
Aluminum Powder	207
Reclamation of U_3O_8 Scrap	9,472
Special Materials Charge	2,000
(ii) Converter Plate Cases	10,651
Aluminum Sheets	210
Boral Sheets	1,656
(iii) Converter Plate Drives	2,697
Gears and Motors for Drives	730
	$31,723

(6) Regulating and Safety Rods and Drives

(i) Seven Regulating-Safety Rods	$ 8,660
(ii) Teleflex Drives	15,000
(iii) Revision of Teleflex Drives	3,000
(iv) Extension Tubes	720
(v) Modified Teleflex Drives	4,584
Clutches, Micro Switches, Shafts, Gears, Cable, etc., for Modified Drives	954
	$32,918

(7) Fuel Assemblies

(i)	Eight Dummy Fuel Assemblies	$ 745
(ii)	Twenty Type-Two Fuel Assemblies	11,620
(iii)	Nineteen Beryllium Cylinders	6,235
(iv)	Nineteen Outer Fuel Tubes (in reserve)	8,574
(v)	Four Fuel-storage Drums	422
(vi)	Fifty Nose Pieces, Inlets, and Thimble Seats	38
		$27,634

(8) Reactor Console and Instrumentation

(i)	Master Console	$55,084
	Additional Instrumentation	3,000
(ii)	Four-instrument Thimbles	705
(iii)	Electrometer	485
(iv)	Background Recorder	1,554
(v)	Three Background Monitors	1,985
(vi)	Period Meter	1,461
(vii)	Safety Trip Circuits	6,300
(viii)	Electronic Galvanometer	3,901
(ix)	Automatic Control Circuit	4,118
		$78,593

(9) Biological Consoles

(i)	Two Instrumented Consoles	$32,000
(ii)	Remote Background Monitors	1,985
(iii)	Remote Background Recorders	1,554
		$35,539

(10) Neutron Shutters and Drives

(i)	Neutron Shutters	$18,277
	Micro Switches, Tubing, Junction Boxes, Solenoid Valves, Fixtures, etc.	3,121
(ii)	Six Nopak Air Cylinders	3,300
(iii)	Air Storage Tank	146
		$24,844

(11) Pneumatic Rabbit Facility

(i)	Rabbit Assembly Housing	$ 1,725
(ii)	Outer Shield Plug Assembly	9,089
(iii)	Extension Tube and Seal Housing	4,421
(iv)	Automatic Timer and Control	7,600
		$22,835

(12) Gas Holder and Circulating System		
	(i) Gas Holder	$ 1,051
	(ii) Catalyst Chamber	853
	(iii) Tubing, Gages, Pipe, Fittings, Flowmeters, Blower, etc.	823
		$ 2,727
(13) Neutron Startup Source		
	(i) Source Assembly	$ 2,911
(14) Installation and Additional Costs		
	(i) Engineering for Concrete Encasements	$ 169
	(ii) Concrete Pad for Steel Shell	1,973
	(iii) Concrete Poured Shielding	2,800
	(iv) Preparation of Converter Plate Areas	1,300
	(v) Reactor Cooling System Screen	523
	(vi) Lead Walls for High- and Low-dose Faces	10,695
	(vii) Changes in above Lead Walls	1,354
	(viii) Graphite Reflector and Thermalizer	2,936
	(ix) Removable Graphite Sections	446
	(x) "Janus" Piping Systems	9,400
	(xi) Helium Control System	1,614
	(xii) Assembly and Installation of Reactor Components	57,170
		$ 90,380
(15) Subcontracted Construction		
	(i) Steel Cases for Pedestals, Shutters and Floor Shielding Blocks	$ 91,735
(16) Miscellaneous Items		
	(i) Fire Prevention Equipment	$ 350
	(ii) Graphic Arts Services	300
	(iii) General Materials and Supplies	5,410
		$ 6,060
	Total Costs Part (a)	$600,518

b. Irradiation Facility Building

(1) Preliminary Design	$ 2,000
(2) Engineering Design	10,752
(3) Field Engineering and Inspection	2,100
(4) Construction (contracted)	107,536
Total Costs Part (b)	$122,388
Total Cost of the "Janus" Facility	$722,906

BIBLIOGRAPHY

1. Reactor Physics Constants, ANL-5800 (July 1958), pp. 462-465.

2. J. N. Anno, A. M. Plummer, and J. W. Chastain, Experience with a 1-Megawatt Pool Research Reactor, Proceedings of the Second UN International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 10, 237 (1958).

3. J. A. Beidelman, J. G. Condelos, and W. H. McCorkle, Safety Analysis Report for the Biological Irradiation Facility ("Janus" Reactor), ANL-6643.

4. Appendix No. 1 to Short Form Construction Contract No. 179 for Cooling Tower Installation Neutron Irradiation Facility, Wing J Building 202 for Argonne National Laboratory, Argonne, Illinois (April 7, 1961), pp. 5-6.

ACKNOWLEDGMENTS

The authors wish to acknowledge the important assistance given in several instances by a number of individuals at this Laboratory.

In particular, recognition is expressed to John Elsbergas for his untiring efforts and major contributions in the design of the nuclear and other control instrumentation of the reactor, to Harry Cern for his very considerable assistance with the mechanical design of the reactor and for his attention to many details required in the preparation of this manual, and to Ruth Schluchter for her conscientious and excellent preparation of the manuscript.